State of California
THE RESOURCES AGENCY

Department of Water Resources

BULLETIN No. 87

SHASTA VALLEY INVESTIGATION

JULY 1964

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources

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TABLE OF CONTENTS

Page

Page

TABLES

PLATES

(Plates are bound at end of bulletin)

FIGURES

PHOTOGRAPHS

APPENDIXES

TE OF CALIFORNIA—RESOURCES AGENCY WILLIAM E. WARNE, Director

PARTMENT OF WATER RESOURCES
BOX 388
RAMENTO

April 29, 1964

Honorable Edmund G. Brown, Governor,
and Members of the Legislature
of the State of California

Gentlemen:

It is my pleasure to transmit herewith the Department of Water Resources Bulletin No. 87, "Shasta Valley Investigation". This investigation was initiated from funds provided by Item 263 of the Budget Act of 1957, and from the Budget Act of 1958.

This final edition contains a statement concerning the public hearing on the preliminary edition of Bulletin No. 87, held in Yreka, California, on December 18, 1963. Comments received at the hearing were given full consideration in preparing the final edition of the report.

The primary objective of the Shasta Valley Investigation was to study possibilities of development of the water resources of Shasta Valley. In attaining this objective, consideration was given both to conservation of the waters of Shasta Valley and importation of water from Klamath River. Based on the findings of the investigation, it was concluded by the department that the Grenada Ranch Project on the Shasta River is the most desirable of the alternative local water development projects studied. Although the benefits from the Grenada Ranch Project exceed the costs, the ratio is small, and the project is marginal under prevailing economic conditions. However, the Grenada Ranch Project is recommended for construction by local interests at such time, and under a method of financing that would establish a satisfactory benefit-cost ratio. It is further concluded that satisfaction of the probable ultimate water requirements of the Shasta River Basin will necessitate importation of water from the Klamath River.

Basic data gathered and information developed during this investigation will be of great benefit to local interests and officials of Siskiyou County and others who may be interested in developing the water resources of the Shasta Valley area.

Sincerely yours,

William E. Warne

Director

Attachment

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

EDMUND G. BROWN, Governor
HUGO FISHER, Administrator, The Resources Agency of California
WILLIAM E. WARNE, Director, Department of Water Resources
ALFRED R. GOLZE, Chief Engineer
JOHN R. TEERINK, Assistant Chief Engineer

NORTHERN BRANCH

John M. Haley . . . . Chief
Stuart T. Pyle . . . . Chief, Planning Section

The Shasta Valley Investigation was conducted and
the preliminary edition of the report dated
July 1961 was prepared under the direction
of

William L. Horn . . . . Chief, Local Project Section

by

M. Guy Fairchild . . . . Supervising Engineer
John O. McClurg . . . . Senior Engineer

Assisted by

John H. Lawder . . . . Senior Engineer
Theodore H. Rhody . . . . Associate Engineer
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Phillip H. Shedd, Jr. . . . . Assistant Civil Engineer

CALIFORNIA WATER COMMISSION

RALPH M. BRODY, Chairman, Fresno

WILLIAM H. JENNINGS, Vice Chairman, La Mesa

JOHN W. BRYANT, Riverside

IRA J. CHRISMAN, Visalia

1/ EDWIN KÓSTER, Grass Valley

JOHN P. BUNKER, Gustine

JOHN J. KING, Petaluma

2/ NORRIS POULSON, La Jolla

MARION R. WALKER, Ventura

-----0-----

WILLIAM M. CARAH
Executive Secretary

3/ ORVILLE ABBOTT
Engineer

Changes in membership of California Water Commission after publication of preliminary edition.

1/ Appointed 2/14/63, succeeding George Fleharty, Redding
2/ Appointed 4/4/62, succeeding Samuel B. Morris, Los Angeles
3/ Appointed 12/1/63, succeeding George Gleason

ACKNOWLEDGMENT

Valuable assistance and data used in this investigation were contributed by agencies of the Federal Government and of the State of California, by cities, counties, public districts, and by private companies and individuals. The Board of Supervisors of Siskiyou County, and the offices under its direction, were most helpful at all times. This cooperation is gratefully acknowledged.

Special mention is made of the cooperation of the following:

Forest Service, United States Department of Agriculture

Soil Conservation Service, United States Department of Agriculture

Bureau of Reclamation, United States Department of Interior

Geological Survey, United States Department of Interior

California Department of Finance

California Department of Fish and Game

California Division of Forestry

California Division of Beaches and Parks

California Public Utilities Commission

University of California at Davis

ACKNOWLEDGMENT (continued)

Fish and Wildlife studies were conducted
in cooperation with the

California Department of Fish and Game

Walter T. Shannon* . . . . .Director

Jack C. Fraser . . . . . . Water Projects Coordinator

Robert Macklin . . . . Fisheries Management Supervisor

John E. Skinner. . . . . Fisheries Biologist III

* Both Messrs. Seth Gordon and William E. Warne served as Director of Fish and Game during the early stages of this investigation.

PUBLIC HEARING
on
Preliminary Edition
of
Bulletin No. 87, Shasta Valley Investigation

In conformance with the Water Code and the Department of Water Resources policy, a public hearing was held on December 18, 1963, in Yreka, California, to receive comments from interested agencies, groups, and individuals on the preliminary edition of Bulletin No. 87, "Shasta Valley Investigation." The hearing immediately followed a hearing on Bulletin No. 83,"Klamath River Basin Investigation," and was attended by about 20 persons including local ranchers, farmers, and representatives of federal, state, and local governmental agencies.

Written comments were received from several state, federal, and local agencies and verbal statements were made by four representatives from the Shasta Valley area. Comments received on the preliminary edition of Bulletin No. 87, and comments received on Bulletin No. 83, concerning the Shasta Valley area, were reviewed and it was found that the main concern of local interests was the proposed Grenada ranch project. Questions were raised as to whether or not the project should be constructed at this time, but no proposals as to the time of construction were made. On the basis of written and verbal comments received, there appear to be no major disagreements over the material presented in the bulletin. However,

Mr. Maxwell, Committee Chairman of the Siskiyou County Water Resources Board, feels that the estimates shown in the report on evaporation from water surfaces, projected population estimated, payment capacity, and irrigation water requirements are slightly low. A review of these estimates was made and it was found that, based on the best available data at this time, there are no sufficient grounds upon which to make revisions in the estimates in question, and therefore, it was concluded that no revisions in the technical material and only minor editorial changes were necessary in finalizing the report. With regard to the foregoing, however, it should be pointed out that future coordinated planning studies by the Department of Water Resources for the area in question will involve a re-evaluation of such items as water use and water requirements, at which time any necessary revisions will be made when more reliable and up-to-date data are available.

A copy of the transcript of the December 18, 1963, hearing is on file with the Department of Water Resources in Sacramento and is available for review by the public. Further, an office report was prepared, setting forth the department's responses to written comments received. The office report is available for limited distribution, and is also on file in the department's office in Sacramento for public review.

Verbal comments were made at the hearing by the following persons:

Mr. M. V. Maxwell, Chairman, Water Resources Board, Siskiyou County

Mr. Stanley Wendt, Manager, Montague Water Conservation District
Mr. C. D. Lawrence, Project Manager, Klamath Project, U. S. Bureau of Reclamation
Mr. Delos Mills, President, Butte Valley Water Development Association
Mr. John J. Linz, Engineer, Soil Conservation Service

Written comments on the preliminary edition of Bulletin No. 87 were received from the following agencies:

State Water Rights Board
Department of Fish and Game
Department of Public Works - Division of Highways
Siskiyou County Board of Supervisors
North Coastal Region Water Pollution Control Board

CHAPTER I. INTRODUCTION

Although the Shasta Valley area has, to some extent, shared in California's recent population growth and economic expansion, the rate of such growth has been considerably less than that of the State as a whole. One of the primary factors in this situation has been the inadequacy of presently developed local water supplies. In recent years the residents of Shasta Valley have shown increasing concern over the problem and have called for a comprehensive investigation to develop a plan for water conservation and utilization, with emphasis on engineering feasibility and economic justification of any proposed projects.

The development of additional water supplies in Shasta Valley would permit additional pasture to be irrigated for livestock and provide increased acreage for diversified farming. Dependable water supplies could attract new industries and possibly provide the impetus for finding new uses for the forest products of the area. Such expansion of agriculture and industry would automatically generate increased urban populations with concurrent demands for increased domestic and municipal water supplies.

Authorization for Investigation

In view of the general concern and widespread local interest in the water problem, a request for funds to conduct an investigation of water resources in Shasta Valley was made by Senator Randolph Collier during the 1956 legislative session. Funds were appropriated by Item 263 of the Budget Act of 1957 which called for:

> " . . . conducting water resources investigations, surveys, and studies, preparing plans and estimates, making reports thereon, and otherwise performing all work and doing all things required relative thereto, Department of Water Resources, in accordance with the following schedule . . ."

A similar item was included in the Budget Act of 1958.

Objective of Investigation

The objective of the Shasta Valley Investigation was to study possibilities of development of the water resources of Shasta Valley. In attaining this objective consideration was given to: (1) possibilities for conserving the waters of the Shasta River and its tributaries, and (2) possibilities for importing water into the valley from the Klamath River. Although the objective could be divided into quite distinct parts, as a matter of engineering practicality it was deemed necessary to concurrently collect data relating to both aspects of the investigation.

Scope of Investigation

The scope of the Shasta Valley Investigation encompassed: (1) complete review of reports of prior investigations of the water resources of Shasta Valley and its tributaries, (2) compilation and evaluation of available data, (3) field surveys to gather new data, (4) engineering and economic analysis of possible plans for water development, and (5) preparation of a final report presenting and evaluating the foregoing items. All evaluations were to be used as a base in estimating the potential increase in economic activity in Shasta Valley which could be expected to result from an increase in the useable water supply, and be embodied in a set of conclusions and recommendations.

Field Surveys

Drilling operations for geologic exploration purposes were conducted at three potential dam sites on the Shasta River during 1958. A geologic reconnaissance study was conducted for one possible dam site on the Klamath River. The study included location and sampling of potential construction materials, borrow areas, and an evaluation of the engineering feasibility of a dam at each site. Engineering designs and estimates of costs were prepared for several sizes of dam at each site and related to estimated project benefits in order to determine the most economical size for each dam and reservoir.

Economic studies provided the basis for project formulation and sizing of project facilities. These studies evaluated the demand for agricultural and municipal water within the watershed and included the determination of payment capacities for agricultural and municipal water users. Irrigation, municipal water use, and recreation benefits which would stem from project developments were evaluated to determine economic justification.

Related Investigations and Reports

A large body of data that had been previously collected by the Department of Water Resources and its predecessor agencies was published in reports of four prior investigations which had, in varying degrees of detail, discussed the water problems of the Shasta Valley. These were reviewed and utilized in evaluation of the plans for water development in the valley. These reports were: (1) the State-wide Water Resources Investigation, results of which were set forth in State Water Resources

Board Bulletins No. 1, and No. 2, and Department of Water Resources Bulletin No. 3, published in 1951, 1955, and 1957, respectively; (2) the Klamath River Basin Investigation, published as Department of Water Resources Bulletin No. 83, May 1960; (3) the Northeastern Counties Investigation, in preliminary form in Department of Water Resources Bulletin No. 58, December 1959, and in final form in June 1960; and (4) investigation of Geology and Ground Water Features of Shasta Valley, published as U. S. Geological Survey Water Supply Paper 1484, 1960. This latter investigation was conducted in cooperation with the Department of Water Resources from 1956 to 1958.

Prior reports containing valuable information and data utilized by the Department of Water Resources in the Shasta Valley Investigation, including the foregoing publications, are listed in the bibliography at the end of this volume, arranged alphabetically by publisher, with each publication being assigned a number for ready reference.

State-wide Water Resources Investigation

The California Legislature, in recognition of the growing statewide water problem, directed the State Water Resources Board, by Chapter 1541, Statutes of 1947, to conduct an investigation of the water resources of California. This study was designated the "State-wide Water Resources Investigation". Funds were provided in the 1947-48 budget for commencement of the investigation and additional funds were provided through 1955-56, by subsequent legislative appropriations.

The State-wide Water Resources Investigation, under direction of the State Water Resources Board, was conducted by the Division of

Water Resources of the Department of Public Works. Three bulletins were published setting forth the results of this investigation. State Water Resources Board Bulletin No. 1, "Water Resources of California", published in 1951, contains a compilation of data on precipitation, unimpaired stream runoff, flood flows and frequencies, and quality of water throughout the State.

State Water Resources Board Bulletin No. 2, "Water Utilization and Requirements of California", published in June 1955, presents estimates of the present use of water throughout the State for all consumptive purposes, and of potential ultimate water requirements, based in general on the capabilities of the land to support further development. The third and concluding phase of the State-wide Water Resources Investigation was reported in Department of Water Resources Bulletin No. 3, entitled "The California Water Plan", published in May 1957. This bulletin presents preliminary plans for the full practicable development of the water resources of the State to meet the potential ultimate water needs therein.

Klamath River Basin Investigation

The Klamath River Basin Investigation involved comprehensive study of the entire Klamath River Basin. The report on the investigation, Department of Water Resources Bulletin No. 83, "Klamath River Basin Investigation", was published in May 1960. Pertinent studies conducted under this investigation included: (1) an inventory of water supplies, both surface and underground; (2) a determination of present and ultimate water requirements predicated upon the full development of all natural resources;

(3) an estimate of the effect on available water supplies of full development of all natural resources, irrigating all potentially irrigable lands, and supplying all estimated urban and industrial requirements; (4) a determination of areas within the basin subject to a deficiency in water supply; and (5) an inventory of possible plans for water development that could provide adequate supplies for all uses.

Northeastern Counties Investigation

The Northeastern Counties Investigation, a detailed study of land and water use covering 15 northeastern counties, including Siskiyou County, was initiated in 1954. A preliminary report on the investigation, Bulletin No. 58, "Northeastern Counties Investigation", was published in December 1957. The final report was issued in June 1960.

Investigation of Geology and Ground Water Features of Shasta Valley

In June 1953, the United States Geological Survey, as part of a cooperative program with the Division of Water Resources, undertook a reconnaissance investigation of the geology and ground water of Shasta Valley. Studies conducted under this investigation included the determination of : (1) the extent and thickness of water-bearing rocks; (2) the physical character and hydrologic properties of those rocks; (3) the occurrence and movement of ground water; and (4) the chemical character of ground water and its relation to occurrence, movement, and use. The results of this investigation were published in 1959 in United States Geological Survey Water Supply Paper 1484, "Geology and Ground Water Features of Shasta Valley, Siskiyou County, California".

Area of Investigation

Shasta Valley, the area of investigation, is located in the central portion of Siskiyou County, one of the three northernmost counties of California. The location of the area is shown on Plate 1, "Location and Hydrographic Units of Shasta River Basin". It will be noted that while the investigation is referred to as the "Shasta Valley Investigation", the term "Shasta River Basin" is sometimes used in discussions of water supply, geology or other subjects, the scope of which are not confined to the valley floor. While the entire basin was investigated, particularly with respect to evaluation of water supplies, emphasis of the investigation was placed on present and future water requirements for irrigable lands and urban areas which are essentially confined to the valley floor. The Shasta River Basin contains approximately 507,000 acres of which 141,000 acres, or about 28 percent of the total, comprise irrigable land, mainly within Shasta Valley.

Natural Features

The Shasta River Basin is roughly an elliptical area with its major axis lying in a north-south direction. The basin is approximately 36 miles long with a maximum width of 30 miles. The easternmost ridges of the Klamath Mountain range form the western border of the basin. The Cascade Range, from Mount Shasta northward, marks the eastern limits. Bogus and Black Mountains are generally considered to define the northernmost limits of the basin. The Siskiyou County line, south of China Mountain, defines the southern rim.

The Shasta River Basin ranges in elevation from 2,000 feet at the mouth of the Shasta River to 14,162 feet at the peak of Mount Shasta, Shasta Valley may be defined as the area within the basin at an elevation of less than 2,800 feet. Although the valley contains approximately 141,000 acres of irrigable land it is not an extensive alluvial valley as are the neighboring Scott and Butte Valleys. A unique feature of the valley is the numerous, small, cone-shaped hillocks scattered throughout the central portion which have the effect of dividing the area into a number of distinctly separated parts. The origin of the cones lies in the volcanic activity of a past geologic era.

A dominant, and certainly the most scenic, feature of the Shasta River Basin is Mount Shasta in the southeast part of the basin. This mountain, an extinct volcano, rises some 11,000 feet above the valley floor. Five perennial glaciers are located on its north and east slopes above an elevation of 10,000 feet. Water melted from these glaciers, together with that from precipitation on the mountains from Mount Shasta northward is the principal source of runoff of the Shasta River, much of which reaches the river by underground rather than surface flow.

While stands of merchantable timber are located on the mountain slopes surrounding Shasta Valley, greater economic value lies in grazing range for cattle. In the lower foothill areas the vegetative cover consists of manzanita, juniper, sagebrush, and native grasses. On the valley floor considerable areas of sagebrush are found, mingled with areas of natural meadow pasture that first attracted the livestock industry.

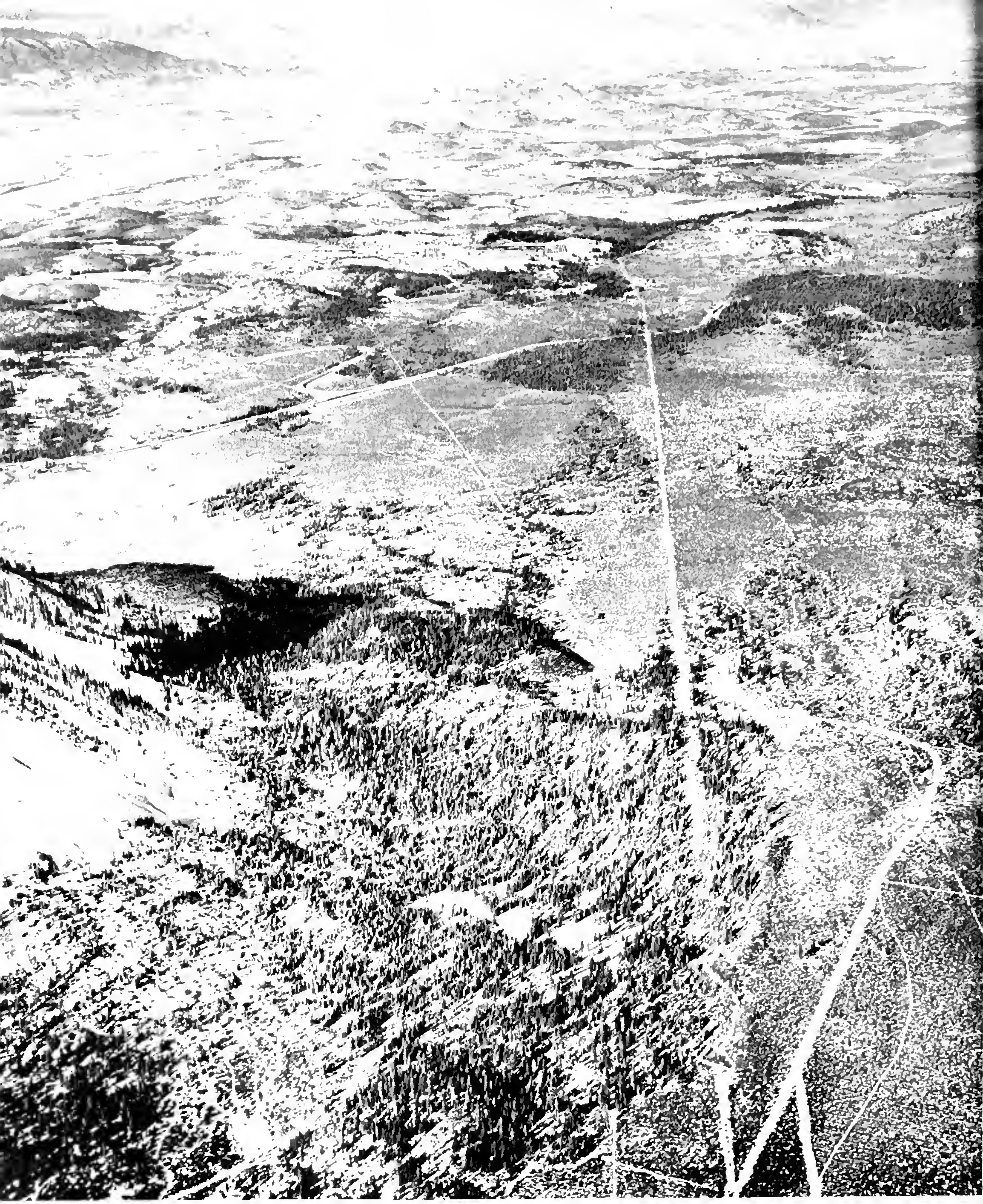
Shasta River has its origin in the high portions of the southwest part of its drainage basin from where Eddy, Dale, and Parks Creeks flow northward to converge with spring flows originating from the southeast. From this juncture, in the vicinity of Big Springs, the river follows a meandering course along the western edge of the valley to a point some seven miles northwest of Montague. Here it leaves the valley and drops about 400 feet in a distance of seven miles, flowing through a steep, rugged canyon to its confluence with the Klamath River.

Little Shasta River originates in the Cascade Range, north of Goosenest, at an elevation of about 6,000 feet and flows westward to join the Shasta River at a point about two miles south of Montague. The porous, fractured lava character of the watershed of Little Shasta River, as well as winter snowfall, contribute to a relatively uniform year-around stream flow.

A number of minor tributaries originate in the mountains along the western boundary of the Shasta River Basin, from Willow Creek north to the Klamath River. These streams are generally short and steep, draining areas of relatively impervious rocks. As a result, few provide continuous flows throughout the year, and total water contributed by them constitutes a minor portion of the total runoff of the Shasta River. However, two of these minor streams, Yreka and Greenhorn Creeks, have been developed as sources of water supply for the City of Yreka.

Climate

Shasta Valley is a region of generally moderate climate with marked changes in temperature and precipitation within relatively short



Aerial View of Shasta Valley looking north.

distances. On the valley floor, temperatures are warm in summer and moderately cold in winter. The maximum recorded temperature at Yreka is 112°F. and the minimum is minus 11°F.; however, these temperature extremes do not represent normal summer or winter occurrences. While the average length of growing season at Yreka is about 180 days, the area is subject to frosts in the late spring and early fall. A summary of temperature data at Montague and Yreka is presented in Table 1. These stations are considered representative of Shasta Valley in this respect.

Storms that traverse the Shasta River Basin generally move from northwest to southeast. This pattern of movement results in heavy precipitation on the Klamath Mountains and along the crest of the ridge defining the westerly boundary of the basin. As the storms move southeastward to cross the basin, a rain shadow effect is observed along the central portion resulting in a much lessened precipitation on the valley floor, the higher elevation along the eastern boundary of the basin causes a lifting and resultant cooling effect on the air masses, thus causing an increase in precipitation. However, since the storms become less intense as each mountain range is crossed, the average precipitation on the Cascade Range is less than the average precipitation on the Klamath Mountains to the west.

Geology

The geology of the Shasta River Basin has a direct effect upon ground water, and the economics of water development projects. Therefore, geology was thoroughly studied during the course of this investigation. A discussion of the geology of the area is included in this report as Appendix A.

TABLE 1

MONTHLY SUMMARY OF RECORDED TEMPERATURE DATA AT
MONTAGUE AND YREKA

(In degrees Fahrenheit)

Month	Montague					Yreka				
	Average monthly values			Extreme values		Average monthly values			Extreme values	
	Maximum	Mean	Minimum	Maximum	Minimum	Maximum	Mean	Minimum	Maximum	Minimum
January	55.2	36.2	12.6	63	- 9	53.6	33.5	12.6	63	-11
February	62.3	41.4	16.8	71	8	59.9	38.0	14.6	69	-11
March	72.9	47.0	18.7	82	14	68.1	43.2	18.9	80	14
April	83.0	50.7	23.3	90	15	78.3	49.7	23.8	90	18
May	92.0	57.8	29.2	99	22	87.0	56.7	28.4	97	23
June	99.8	64.4	36.2	106	29	94.3	63.2	33.6	105	31
July	103.8	73.1	44.6	110	36	98.4	71.9	41.5	112	38
August	103.5	71.9	41.9	110	34	96.9	70.4	40.2	108	36
September	97.7	64.0	32.6	103	25	93.7	64.3	33.2	107	27
October	87.0	53.2	24.5	95	16	81.9	53.4	25.3	94	21
November	65.7	41.2	16.5	75	9	63.4	41.6	17.8	75	8
December	58.4	35.6	13.5	64	-15	55.6	35.8	13.8	66	- 6

The geology of the Shasta River Basin is complex and includes a wide variety of metamorphic and intrusive igneous rock such as schist, marble, metachert, quartzite, greenstone, chlorite schist, and meta-diabase. A chain of extinct volcanoes, one of which is Mount Shasta, forms the eastern edge of the Shasta River Basin. Pumice was reportedly blown from Mount Shasta as recently as 1786. Moraines and glacial outwash deposits cover an area of about 35 square miles in the southeastern part of Shasta Valley. These consist mainly of coarse, poorly sorted, bouldery deposits containing abundant sand, silt, clay, and rock flour. Alluvial fans, composed of sandy and gravelly outwash, are still accumulating debris provided by existing glaciers on Mount Shasta.

Shasta Valley may be divided into four areas having rather distinct geologic, hydrologic, and topographic characteristics. The eastward sloping plain is relatively featureless, having been formed by the recent deposition of alluvium along several small streams flowing from the west. The hillock and flat area includes the knolls and ridges which protrude from a few feet to as much as 800 feet above the alluviated valley floor. Basalt flow, called "Pluto's Cave Basalt", covers the southeasterly quarter of Shasta Valley. From a distance the flow appears to have a gentle westward slope but, when viewed close up, the surface is seen to be broken by jagged outcrops.

Most of the northern end of Shasta Valley, north and west of Montague, is covered by older alluvium which is composed mainly of poorly sorted, gravelly, sandy clay, deposited by streams on alluvial fans.

These fans form an old alluvial plain which has a gently rolling, eroded surface, strewn with large volcanic boulders.

Fresh fault scarps along the east side of the valley provide evidence that earthquakes have taken place in the recent geologic past. Displacements of the crust along these still active faults could cause earthquakes at any time.

Soils

Soils of the Shasta River Basin differ markedly as to their manner of formation, parent rock source materials, and age. These differences are significant when considering crop adaptabilities of the various soils within the basin. They can be arranged rather broadly into four groups: (1) recent and young alluvial soils, (2) morainic (Glacial) soils, (3) older valley filling soils, and (4) upland or residual soils.

These soils have been severely modified by relatively recent volcanic activity in the Mount Shasta region. Many ridges and mounds of extruded volcanic-type rocks have broken Shasta Valley into numerous small and sometimes isolated pockets of irrigable soils. Glacial action has left an extensive area of coarse textured, stony, morainic soils in the southern end of the valley. Some limited areas of alkali are scattered throughout the valley. However, analysis of soil samples has indicated that the alkaline areas are neither extensive nor severely alkaline. The older valley fill soils of Shasta Valley are typified by the very shallow, undulating hardpan soils found in the vicinity of Montague.

The major portion of the soils in Shasta Valley are limited in their crop adaptability by the presence of rock, root restricting hardpans,

and parent materials, or very coarse textures. Local spring flooding and a short growing season restrict the crop adaptability. Such crops as pasture, alfalfa, small grains, and a restricted selection of field crops will probably constitute the major portion of the future cropping pattern for the valley.

Development

Waters of the Shasta River Basin were used extensively in early mining operations, and many of the present-day patterns of water use originated in the early gold rush days. The Yreka Ditch, which originally had a total length of about 90 miles, was constructed by Chinese coolie labor to convey water to mines in the vicinity of Hawkinsville, north of the City of Yreka. This lengthy transmission of water did not prove practical due to extensive losses, and, at present, only the first 15 miles of the Yreka Ditch are used to convey water from the Shasta River and Parks Creek for irrigation use in the vicinity of Gazelle.

After the initial gold mining boom subsided and increasing numbers of the settlers turned to lumbering, agriculture, and cattle raising, the use of the waters of the Shasta River Basin became increasingly important. As the patterns of water supply and demand do not coincide with each other, and the seasonal water supply tends to have a wide variation, disputes over water distribution have occurred with increasing frequency. In December 1932, the waters of the Shasta River Basin were adjudicated by the Superior Court of California and, since 1934, the available water resources have been apportioned by the Department of Water Resources Watermaster Service.

During the period from 1912 to 1925, four water service agencies were formed to provide water to about 10,000 acres in Shasta Valley. These were the Shasta River Water Users Association, Grenada Irrigation District, Montague Water Conservation District, and Big Springs Irrigation District. Water supplies were obtained by these agencies principally by direct diversion of unregulated stream flow. However, one major storage reservoir, Dwinnell Reservoir on Shasta River below Edgewood, with a present useable storage capacity of about 50,000 acre-feet, was constructed in 1928. Water from Dwinnell Reservoir is conveyed by canal 20 miles northward to furnish irrigation and domestic water to Little Shasta Valley and the northeasterly portion of Shasta Valley in the vicinity of Montague.

The most extensive urban and industrial requirements for water in Shasta Valley are concentrated in the Yreka area. Until 1959, wells were depended upon to provide water to meet these requirements. In the summer of 1959, however, Yreka initiated construction of Greenhorn Reservoir on Greenhorn Creek. This reservoir now provides supplemental water for domestic and municipal uses of the City of Yreka during the summer months.

The major industries in Shasta Valley are associated with agriculture and lumbering, the agricultural industry operating primarily to support cattle raising. The large number of beef cattle raised in the valley create a sizeable demand for locally grown feed, which has resulted in the establishment of two pellet mills during the last few years, thereby affording improved feeding practices.

Alfalfa and grain are the principal crops grown in Shasta Valley. From 1900 until the late 1920's, however, there was more diversification

of local agricultural practices when fruit and vegetables were raised for local consumption. As transportation facilities into the valley improved, produce from competing areas was made available at more reasonable prices than that grown locally. Thereafter, the acreage planted to fruit and vegetables was converted to the present pattern of supporting the livestock industry. The improvement of transportation facilities broadened the marketing area for local hay, grain, and dairy products, resulting in the present exportation of approximately 50 percent of the hay and grain grown in the valley. Principal market centers for hay shipped from the valley are the Eureka-Arcata, Grants Pass-Roseburg, and Langlois-Coos Bay areas. Although there is one meat packing plant at Gazelle, most beef is shipped from the valley on the hoof.

Individual farmers are striving to increase agricultural production in Shasta Valley by greater use of fertilizer, sprinkler systems, leveling of lands, construction of farm ponds, and general improvement of farming practices. There is some experimentation with crop diversification, and the raising of crops such as field corn and potatoes has given evidence of an agricultural potential in the valley which previously had not been given serious consideration.

The lumbering industry in the Shasta Valley area has been a primary factor in the local economy since the earliest days. Pine, fir, and cedar are cut from the mountainous area within the basin and logs are brought in from nearby areas for processing. The Long Bell Mill at Weed, one of the largest mills in the State, processes veneer logs from forests in Northern California and Southern Oregon. Other large lumbering operations

are located at Yreka, Montague, Mount Shasta City, and McCloud. It is estimated that some 130,000,000 board feet of saw logs are cut annually in Siskiyou County, and that some 40,000,000 board feet are imported for processing. Exports of lumber to be processed outside the county are estimated to total about 60,000,000 board feet per year.

Transportation facilities in Shasta Valley are adequate for the economy of the area and play a significant role in its commerce. The valley is served by Highway 99, and Highway 97. A Southern Pacific Railroad mainline traverses the valley, with frequent freight service to Montague. Since World War II, highway and railroad improvements have resulted in lowering the cost of shipping to and from the valley by almost 50 percent.

Population

Siskiyou County has not experienced the phenomenal increase in population which has characterized many areas in California. The results of the 1960 census showed a total county population of 32,762, as against a 1950 population of 30,730 or an increase of only 6.6 percent. During the same period the population of the City of Yreka increased from 3,230 to an estimated 4,300, or an increase of about 27 percent. However, other urban areas in the county did not show the same increase. It is anticipated that substantial population growth will occur in the future.

CHAPTER II. WATER SUPPLY

The water supply of Shasta Valley is derived principally from precipitation and melting snow from the surrounding mountains, and particularly from Mount Shasta, which produces the major portion of the total annual runoff in the late spring and early summer months. By late summer the streams of the Shasta River Basin have reached their points of least seasonal flow and are sustained only by springs and areas of effluent seepage. The resulting seasonal runoff pattern is one of peak flows in the winter and late spring months and low flows during the summer months.

Direct diversion of unregulated stream flow is the principal method employed to obtain water for irrigation and domestic purposes. A minor amount of water is imported into the valley from the Upper Sacramento River Basin, but the amount is of negligible significance in relation to the total water supply. Ground water exists in the areas of alluvial fill and, in many places, water supplies are obtained from wells for municipal, domestic, stock watering, and irrigation purposes. Considerable ground water storage capacity exists in the Pluto's Cave basalt area in the southeastern part of Shasta Valley. In the western and southern portions of the valley, however, ground water development is limited because of shallow depths of water-bearing formations. Surface and ground waters are generally of good quality.

During this investigation certain periods were chosen for detailed analysis of the hydrology of the Shasta River Basin. These periods, their definitions, and the reasons for their selection are set forth in the following paragraphs, and they will be so used throughout this bulletin.

Mean Period--A period chosen to represent conditions of water supply and climate existing during a long period of years. For the purpose of this bulletin, the 60-year period from 1894-95 through 1953-54 was considered representative of runoff and the 50-year period from 1905-06 through 1954-55, was selected as being representative of precipitation.

Base Period--A period for which reliable records are available, and during which the conditions of water supply and climate are representative of those occurring during the mean period. For purposes of this bulletin, the 35-year period 1920-21 through 1954-55 was chosen for water supply and reservoir operation studies. Average annual runoff during this base period was about 95 percent of that of the mean period.

Both of these periods contain the critical periods of 1923-34 and from 1927-28 through 1934-35, during which minimum stream flows were recorded. Analyses of reservoir operation were made for these periods to determine firm yields.

Precipitation

The Shasta River Basin lies within the area traversed by storms which sweep inland from the north Pacific during winter and spring months. Precipitation from these storms is light on the valley floor and generally increases to moderately heavy in the surrounding mountains.

As mentioned in Chapter I, a general study of the amounts and characteristics of precipitation in the Shasta River Basin was made as part of the Klamath River Basin Investigation. Data developed by these

Dwinnell Dam and Reservoir looking southwest.

studies were reviewed during the Shasta Valley Investigation and refined as new data were gathered.

Precipitation Stations and Records

The longest continuous period of record of any precipitation station in the Shasta River Basin is that of the Yreka Precipitation Station, for which records have been kept since 1870. All other stations in the basin have much shorter periods of record, many having been kept only on an intermittent basis. The lack of precipitation stations in the eastern and southern portions of the basin posed a particular problem in attempting to estimate precipitation over the area as a whole.

The 20 precipitation stations and 17 snow courses from which data were obtained during this investigation are shown on Plate 2 "Lines of Equal Mean Seasonal Precipitation for Shasta Valley and Vicinity". Map reference numbers for precipitation stations shown on this plate designate the major drainage basin in which each station is located and its United States Weather Bureau identification number. The California numbers for snow survey courses are assigned by the Department of Water Resources and indicate the chronological order in which the courses and stations were established.

A number of factors cause the records at these stations to be of limited accuracy or reliability, especially when utilized to determine overall geographic or chronologic patterns of precipitation. As may be seen from Plate 2, the precipitation stations in or adjacent to the basin are not well distributed, most of them being located in the northern and western portions of the area of investigation. It was necessary, therefore, to extrapolate from the records of the existing stations, or to make

estimates based on available data, in order to find patterns for the 35-year base period.

Seventeen snow courses located in or adjacent to the Shasta River Basin are measured and maintained as part of the California Cooperative Snow Surveys. These stations range in elevation from 2,500 to 7,900 feet, with eleven of them lying between 5,700 to 7,000 feet. Since the highest elevation at which a precipitation gage is located is 4,486 feet, measurements as these snow courses constitute the only available records of precipitation for the higher elevations in or adjacent to the basin.

The precipitation stations, together with their elevations, periods and sources of record, and values of mean, maximum, and minimum seasonal precipitation are presented in Table 2. Similar data for the snow courses are presented in Table 3. Where necessary, precipitation records were extended to cover the 50-year mean period by direct correlation with nearby stations during periods of natural record. Records of precipitation at these stations, as well as for the snow courses, have been published in bulletins of the United States Weather Bureau and the Department of Water Resources.

Precipitation Characteristics

The average seasonal depth or precipitation in the Shasta River Basin varies from a minimum of about 5 inches in the vicinity of Big Springs, to about 50 inches on China Mountain, and over 70 inches on Mount Shasta. The maximum recorded seasonal depth of precipitation in or adjacent to the basin occurred at the Mount Shasta Weather Bureau Station during the season of 1889-90 when the total reached 73.47 inches. The

TABLE 2

PRECIPITATION STATIONS IN AND ADJACENT TO SHASTA RIVER BASIN

Reference number (a) on Plate 3	Station	Elevation in feet	Period of record	(b) Source of record	Seasonal depth of precipitation: 50-year mean 1905-1955, in inches	Recorded maximum and minimum: Season	Recorded maximum and minimum: Inches
F3 0721	Betts Ranch	2,650	1944 - 1958	U.S.W.B.	14.38	1955-56 1954-55	22.52 7.08
F3 1997	Copco #1 Dam	2,700	1928 - 1952	O.A.E.S.	16.29	1937-38 1938-39	23.58 8.70
F2 2680	Edgewood	2,963	1888 - 1948	U.S.W.B.	20.24	1940-41 1938-39	39.12 9.15
F2 2899	Etna	2,950	1940 - 1958	Private U.S.F.S.	24.14	1955-56 1954-55	39.31 11.61
F2 3176	Fort Jones 6	3,400	1942 - 1958	U.S.W.B.	17.72	1955-56 1954-55	29.02 7.66
F2 3182	Fort Jones R.S.	2,747	1936 - 1958	U.S.W.B.	20.16	1957-58 1954-55	33.63 9.63
F2 3614	Greenview	2,818	1943 - 1958	U.S.W.B.	20.25	1955-56 1943-44	34.42 12.77
F2 3633	Grenada	2,560	1928 - 1930	Private	17.38	1926-27 1917-18	20.91 6.40
F3 3988	Hilt Slash Disposal	2,915	1933 - 1958	U.S.W.R.	20.20	1955-56 1954-55	35.93 9.41
F3 4105	Hornbrook	2,154	1888 - 1916	U.S.W.B.	13.42	1889-90 1912-13	25.65 6.85
F2 5785	Montague 3 N.E.	2,640	1948 - 1958	U.S.W.B.	10.33	1955-56 1954-55	17.48 4.89

TABLE 2 (continued)

PRECIPITATION STATIONS IN AND ADJACENT TO SHASTA RIVER BASIN

Reference number (a) on Plate 3	Station	Elevation in feet	Period of record	(b) Source of record	Seasonal depth of precipitation: 50-year mean 1905-1955, in inches	Recorded maximum and minimum: Season	Recorded maximum and minimum: Inches
F2 5783	Montague	2,517	1888 - 1948	U.S.W.B. D.W.R.	12.58	1889-90 1897-98	24.19 4.14
F2 5941	Mt. Hebron R. S.	4,250	1942 - 1958	U.S.W.B.	9.78	1957-58 1954-55	20.05 4.37
F3 6328	Oak Knoll R. S.	1,963	1942 - 1958	U.S.W.B.	21.50	1957-58 1954-55	37.73 11.01
F2 8025	Sawyers Bar R. S.	2,175	1933 - 1958	U.S.W.B. U.S.F.S.	42.44	1957-58 1954-55	73.51 24.17
F2 8050	Scott Bar	1,800	1922 - 1935	U.S.W.B.	26.67	1926-27 1923-24	49.18 15.04
	Siskiyou Summit	4,486	1899 - 19 1948	U.S.W.B.	36.57	1920-21 1943-44	54.41 15.30
F2 8324	Soap Creek	3,500	1942 - 1947	U.S.W.B.	20.22	1942-43 1946-47	25.56 13.60
F2 9419	Walla Walla Creek	2,570	1853 - 1892	U.S.W.B.		1889-90 1874-75	49.97 12.72
F2 9866	Yreka	2,625	1871 - 1958	U.S.W.B. U.S.F.S.	17.32	1904-05 1954-55	31.29 7.08

(a) Employed by Department of Water Resources--Meteorologic Unit.
(b) U.S.F.S.-- United States Forest Service
U.S.W.B.-- United States Weather Bureau
O.A.E.S.-- Oregon Agricultural Experiment Station
D.W.R. -- Department of Water Resources

TABLE 3

SNOW SURVEY COURSES IN AND ADJACENT TO SHASTA RIVER BASIN

California number	Station	Elevation: in feet	First year of record	(a) Source of record	Average water content as of April 1: 50-year mean 1905-1950, in inches	Recorded maximum and minimum: Season	Recorded maximum and minimum: Inches
1	Parks Creek	6,900	1936	U.S.D.A.	33.7	1952 1948	57.5 17.5
2	Little Shasta	6,200	1946	U.S.D.A.	26.4	1952 1947	35.0 11.9
3	Sweetwater	5,900	1936	U.S.D.A.	14.4	1952 1947	30.0 6.1
4	Etna Mountain	5,900	1951	U.S.D.A.	47.5	1952 1955	80.6 22.2
5	Middle Boulder #1	6,600	1946	U.S.D.A.	34.2	1958 1948	53.6 19.0
9	Deadfall Lakes	7,200	1946	U.S.D.A.	34.7	1958 1948	51.4 16.8
13	Wolford Casin	6,400	1949	U.S.D.A.	42.3	1952 1955	58.6 21.9
15	Mumbo Basin	5,700	1947	U.S.D.A.	27.1	1952 1955	45.1 7.9
18	Mount Shasta	7,900	1930	U.S.D.A.	52.6	1938 1934	120.4 21.6
19	Sand Flat	6,800	1945	U.S.D.A.	43.4	1958 1947	80.0 29.4
20	North Fork Sacramento	6,800	1936	U.S.D.A.	22.7	1941 1939	45.3 9.9

TABLE 3 (continued)

SNOW SURVEY COURSES IN AND ADJACENT TO SHASTA RIVER BASIN

California number	Station	Elevation: in feet	First year of record	(a) Source of record	Average water content as of April 1: 50-year mean 1905-1950, in inches	Recorded maximum and minimum: Season	Recorded maximum and minimum: Inches
21	Gray Rock Lakes	6,200	1941	U.S.D.A.	45.6	1952 1944	65.1 27.7
285	Swampy John	5,500	1951	U.S.D.A.	48.9	1952 1955	77.6 26.6
298	Dynamite Meadow	5,700	1955	U.S.D.A.	not established	1958 1959	24.0 19.5
311	Middle Boulder #3	6,200	1948	U.S.D.A.	30.9	no record	
325	Scragg Mountain	6,200	1941	O.S.C.S.	30.7	no record	
326	Hazelview	2,500	1955	O.S.C.S.	no snow on course		

(a) U.S.D.A.--United States Department of Agriculture
O.S.C.S.--Oregon Soil Conservation Service

maximum recorded snowpack in the basin, which was 225 inches deep, occurred at the Mount Shasta snow survey course on April 29, 1938, with a content of 122.8 inches of water.

The average monthly distribution of precipitation throughout the year at Yreka is presented in Table 4. About 70 percent of the seasonal precipitation at this station occurs during the 5-month period from November 1 to March 31. Recorded seasonal precipitation at Yreka from 1871 through 1955 is presented in Table 5.

Although precipitation on the Shasta River Basin varies between wide limits from season to season, the seasonal distribution tends to follow the same pattern.

Runoff

Surface runoff from any watershed may be considered under one of two general classifications--"natural runoff" or "impaired runoff". The term "natural runoff" refers to the flow of a stream as it would be if unaltered by upstream diversion, storage, import, export, or change in upstream consumptive use caused by development. The term "impaired runoff" refers to the actual flow of a stream at any given stage of upstream development and, in the case of past flows, constitutes the historical record.

Surface runoff within the Shasta River Basin constitutes the present major source of water supply available to Shasta Valley. Extensive use of this supply, primarily by direct diversion of unregulated stream flow, is made for irrigation purposes. A substantial portion of the winter runoff of the basin is unregulated and is a potential source of water which could be developed to partially meet ultimate water demands of the valley for irrigation and municipal purposes, or fully meet future demands for an undetermined number of years.

TABLE 4

AVERAGE MONTHLY DISTRIBUTION OF PRECIPITATION AT YREKA
FOR THE PERIOD FROM 1899-1900 THROUGH 1948-49*

Month	Precipitation	
	Inches	Percent of seasonal average
January	2.72	15.1
February	2.65	14.6
March	1.78	9.8
April	1.04	5.7
May	0.93	5.1
June	0.67	3.7
July	0.36	2.0
August	0.31	1.7
September	0.55	3.0
October	1.27	7.0
November	2.72	15.1
December	3.12	17.2
TOTALS	18.12	100.0

* From Bulletin No. 83, "Klamath River Basin Investigation".

TABLE 5

RECORDED SEASONAL PRECIPITATION AT YREKA

(In inches of depth)

Season	Precipitation	Season	Precipitation	Season	Precipitation
1871-1872	14.25 [a]	1904-1905	20.28	1934-1935	14.44
73	12.04	06	22.10	36	19.81
74	12.77	07	25.54 [a]	37	13.85
		08		38	26.50
1874-1875	10.20	09		39	10.16
76	22.04				
77	14.02	1909-1910		1939-1940	22.29
78	18.73	11		41	20.28
79	13.32	12		42	23.63
		13		43	21.85
1879-1880	17.57	14		44	10.89
81	20.48				
82	13.08	1914-1915		1944-1945	15.68
83	12.16	16	17.29	46	17.37
84	16.20	17	12.67	47	11.61
		18	11.03	48	18.31
1884-1885	19.68	19	19.63	49	15.30
86	18.95				
87	19.03	1919-1920	9.25	1949-1950	14.21
88	15.70	21	21.96	51	24.60
89	10.42	22	14.61	52	24.42
		23	13.80	53	24.23
1889-1890	30.42 [a]	24	7.89	54	20.50
91	12.92 [a]				
92	14.12 [a]	1924-1925	26.25	1954-1955	7.08
93	16.53	26	11.83		
94	30.50	27	27.38		
		28	15.39	Estimated	
1894-1895	19.75	29	11.33	average for	
96	23.28			mean period	17.85
97	20.84	1929-1930	14.88		
98	13.05	31	13.46	Average for	
99	12.41	32	15.32	base period	17.03
		33	13.75		
1899-1900	18.11	34	11.07	Estimated	
01	23.55			average for	
02	19.34			50-year period	
03	16.12 [a]			from 1899-1900	
04	31.29 [a]			through	
				1948-49	18.12

a Partially estimated

Stream Gaging Stations and Records

Available records of runoff of the Shasta River Basin were used in the hydrologic studies of the Shasta Valley Investigation. However, records of stream flow at the dam sites considered for potential water development were nonexistent. No records of runoff extend over the entire 35-year base period, most of them having been of short or intermittent duration.

Only two stream gaging stations in Shasta Valley are currently being operated on a year-round basis. The United States Geological Survey has maintained a gaging station on the Shasta River near Yreka continuously since December 1944. Prior records for this station cover the period from October 1933 to December 1941. The gaging station of the Montague Water Conservation District, located on the Shasta River at Edgewood Bridge, has been in continuous operation since April 1940. This station is operated by the Watermaster Service of the Department of Water Resources during the irrigation season and by the district during the winter months.

The United States Geological Survey operated a gaging station on the Shasta River near Montague prior to 1933. Since that time, this station has been operated by the Department of Water Resources Water-Master Service during the irrigation season only. The Watermaster Service operates several other gaging stations in Shasta Valley during the irrigation season, and publishes records of stream flow for these stations in the form of annual reports. However, since considerable use and re-use occurs above these gages and as the records cover only the

period during the irrigation season, these intermittent data were of limited value in developing a record of water supply at potential reservoir sites. The annual reports of the Watermaster Service are on file with the Department of Water Resources.

During the Klamath River Basin Investigation four new gaging stations were installed on tributaries of the Shasta River and operated from 1953 to 1956. Four of the Watermaster Service gages, previously operated during the summer months only, were reinstalled with gages of greater range, suitable for winter flows, and operated year-round during the same period of time. Staff gages were installed on a number of minor tributaries and read on a monthly schedule, or more frequently during rapid changes in quantity of surface runoff.

Table 6 lists the stream gaging stations shown on Plate 2, together with their reference numbers, drainage areas above stations, and periods and sources of record. Data taken from these stations were used to derive meaningful relationships pertinent to an understanding of the hydrography of the Shasta River Basin. Gaging stations on the Klamath River are listed because of their importance in any analysis of possibilities for obtaining waters from the Klamath River for use in Shasta Valley. The reference numbers for the stations listed in Table 6 correspond to those used in State Water Resources Board Bulletin No. 1, "Water Resources of California", and in Department of Water Resources Bulletin No. 83, "Klamath River Basin Investigation".

TABLE 6

STREAM GAGING STATIONS IN AND ADJACENT TO SHASTA RIVER BASIN

(a) Reference number	Stream	Station	Drainage area in square miles	Periods of record	Sources of record (b)
1 - 7	Fall Creek	at Copco	20	1928-58	U.S.G.S.
1 - 8	Klamath River	below Fall Creek, near Copco	4,370	1928-58	U.S.G.S.
1 - 8A	Klamath River	near Copco	4,350	1923-28	U.S.G.S.
1 - 9	Jenny Creek	near Copco	(c)	1923-24	U.S.G.S.
1 - 10	Shasta River	above Edson--Foulke Ditch	(c)	1934-58 (d)	D.W.R.W.
1 - 11	Beaughan Creek	below Long Bell	(c)	1923-58 (d)	D.W.R.W.
1 - 12	Shasta River	at Edgewood Bridge	71	1936-38 1940-50	D.W.R.W.
1 - 13	Carrick Springs	near Weed	---	1934-58 (e)	D.W.R.W.
1 - 14	Parks Creek	above Duke North Ditch	19	1934-58 (d)	D.W.R.W.
1 - 15	Parks Creek	at Robertson Weir	(c)	1934-58 (d)	D.W.R.W.
1 - 16	Big Springs	at Head	---	1934-58 (e)	D.W.R.W.
1 - 18	Little Shasta River	above Harp Ditch	46	1928-58 (f)	D.W.R.W.
1 - 19	Cleland Springs	at Head	---	1928-57 (e)	D.W.R.W.
1 - 20	Shasta River	near Montague	670	1911-13 1917-34 1934-58 (g)	U.S.G.S. D.W.R.W.
1 - 21	Shasta River	near Yreka	796	1933-41 1945-58	U.S.G.S.
KRB-49	Bogus Creek	near Bogus School	27	1953-54	D.W.R.
KRB-56	Yreka Creek	at Yreka	20	1953-54	D.W.R.
KRB-57	Greenhorn Creek	at Yreka	12	1953-54	D.W.R.

TABLE 6 (continued)

STREAM GAGING STATIONS IN AND ADJACENT TO SHASTA RIVER BASIN

(a) Reference number	Stream	Station	Drainage area in square miles	Periods of record	Sources of record (b)
KRB-64	Willa Creek	near Gazelle	12	1953-54	D.W.R.
KRB-66	Whitney Creek	at U.S. Highway 97	(c)	1952-53	D.W.R.
KRB-67	Parks Creek Diversion to Shasta River	near Edgewood	---	1934-58	D.W.R.W.
KRB-68	Edson--Foulke Ditch	north of Parks Creek	---	1953-54	D.W.R. D.W.R.W.

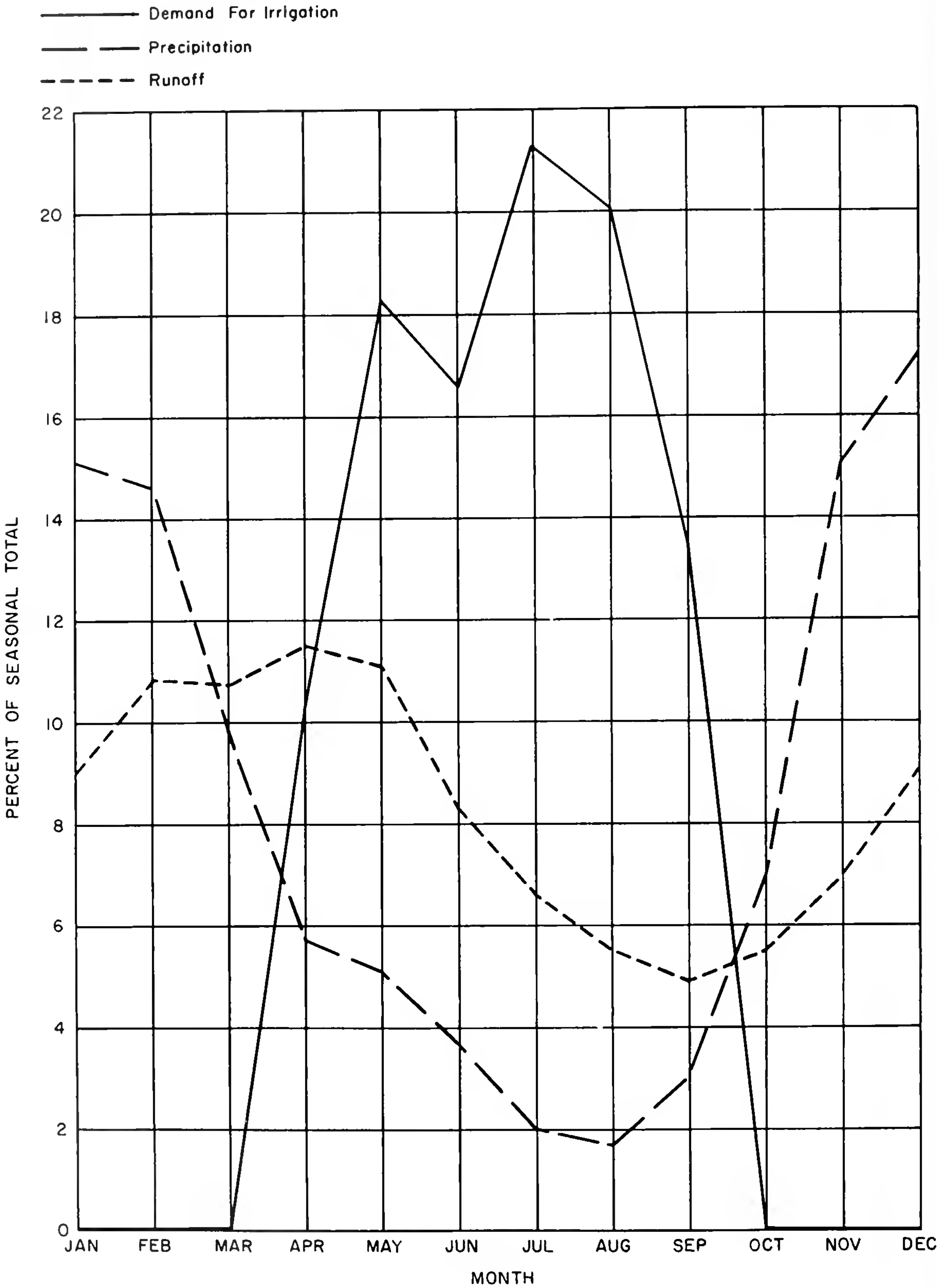
(a) Department of Water Resources Bulletin 1 or Klamath River Basin Investigation reference numbers.
(b) U.S.G.S.--United States Geological Survey.
D.W.R. --Department of Water Resources.
D.W.R.W.--Department of Water Resources, Watermaster Service.
(c) Not measured.
(d) Irrigation season records only.
(e) Occasional irrigation season measurements only.
(f) Irrigation season records only until 1955.
(g) Irrigation season records only since 1934.

Runoff Characteristics

As runoff from the Shasta River Basin is derived primarily from direct precipitation and snowmelt, peak flows of the streams are reached in the winter and late spring months and the low flows occur during the summer months. The Shasta River, however, has well sustained summer flow characteristics. This is due to the predominance of the volcanic structure of the basin, which rapidly absorbs and stores precipitation and yields the stored water at a comparatively even rate of flow.

The differing rates and patterns of direct precipitation, snowmelt, runoff, and demand create a situation in which these factors are seldom in harmony with each other. Figure 1 "Comparison of Seasonal Precipitation, Natural Runoff, and Demand" depicts the situation graphically. Figure 1 strikingly illustrates the monthly imbalance between water supply and demand.

The estimated average seasonal natural runoff of Shasta River near Yreka, during the 35-year base period, was 162,300 acre-feet. However, seasonal runoff during the 60-year mean period varied from a maximum of slightly over 170 percent during 1903-04 (278,000 acre-feet) to a minimum of slightly more than 60 percent during 1923-24 (101,000 acre-feet). Table 7 presents the estimated average monthly distribution of natural runoff of Shasta River near Yreka for the period from 1920-21 through 1954-55, and monthly percentages of the seasonal total. Monthly percentages shown in this table were used to plot the "runoff" curve on Figure 1.



COMPARISON OF SEASONAL PRECIPITATION, NATURAL RUNOFF AND DEMAND

TABLE 7

ESTIMATED AVERAGE MONTHLY DISTRIBUTION OF NATURAL RUNOFF OF SHASTA RIVER NEAR YREKA FOR THE PERIOD 1920-21 THROUGH 1954-55

Month	Runoff: In acre-feet	Runoff: In percent of seasonal total	Month	Runoff: In acre-feet	Runoff: In percent of seasonal total
October	8,900	5.5	April	18,600	11.5
November	11,200	6.9	May	18,100	11.1
December	14,900	9.2	June	13,500	8.3
January	14,700	9.0	July	10,700	6.6
February	17,500	10.8	August	8,900	5.5
March	17,300	10.7	September	8,000	4.9
TOTALS				162,300	100.0

Minor streams of the eastern portion of the Shasta River Basin have relatively uniform monthly flow characteristics. The apparent reason for this uniform flow lies in the fact that the southeast quadrant of the valley contains a large area of highly permeable volcanic rocks and overburden which absorb an unusually high percentage of precipitation and snowmelt. These percolated waters reappear as discharge from numerous springs, the largest of which are located in the vicinity of Big Springs Creek. Some of the small creeks which drain the northwesterly slopes of Mount Shasta contain water only during the evening hours of summer months, after long hours of sunlight on the glaciers of the mountain. The flow of these creeks seldom reaches the Shasta River as surface runoff, because of percolation in the Juniper Flat area.

Quantity of Runoff

Since none of the stream gaging stations in the Shasta River Basin was in continuous operation during the base period, and there are no gaging stations located at the dam sites considered, it was necessary to estimate runoff at selected stations. These estimates were made during previous investigations conducted by the Department of Water Resources, and were reviewed and extended as part of this investigation. Recorded historic and present impaired seasonal runoff of the Shasta River near Yreka during the base period is set forth in Table 8. Similar data for the Klamath River at Copco are presented in Table 9.

Flood Flows

Flood flows in the Shasta River Basin occur almost every year in the winter and spring months, and generally result from snowmelt runoff or a warm rain on an existing snowpack. The peaks of these floods are reduced by the high absorption characteristics of the area and by the effects of the broad, flat plain of Shasta Valley. During times of extreme flood run-off, waters leave the natural channel of the Shasta River and are temporarily partially stored in adjacent flatland areas. However, areas subject to flooding are small and, being generally underdeveloped, are seldom subject to damage.

The maximum recorded flow of the Shasta River occurred on December 27, 1955, when a flow of 6,090 second-feet was recorded at the United States Geological Survey gaging station near Yreka. Since 1929, flood flows of the Shasta River have been partially regulated by Dwinnell Reservoir, which normally has available capacity for storage of flood

TABLE 8

NATURAL, RECORDED HISTORIC, AND PRESENT IMPAIRED SEASONAL RUNOFF
OF SHASTA RIVER NEAR YREKA
FOR THE BASE PERIOD 1920-21 THROUGH 1954-55

(In acre-feet)

Season	Estimated natural runoff	Recorded historic runoff	Estimated present impaired runoff
1920-21	206,000		173,600
22	127,000		105,900
23	121,000		100,400
24	101,000		73,700
1924-25	182,000		94,000
26	128,000		88,400
27	241,000		152,700
28	160,000		121,900
29	121,000		81,000
1929-30	131,000		81,900
31	111,000		61,400
32	123,000		62,600
33	123,000		63,800
34	112,000	56,500	55,200
1934-35	119,000	65,900	61,000
36	131,000	79,200	74,200
37	125,000	70,800	69,100
38	249,000	208,500	195,300
39	114,000	76,700	87,900
1939-40	188,000	146,000	131,200
41	261,000	210,600	194,000
42	204,000		199,500
43	153,000		110,000
44	123,000		84,400
1944-45	144,000	99,000	92,400
46	169,000	114,200	105,900
47	142,000	80,500	73,800
48	187,000	108,100	96,600
49	160,000	99,200	97,100
1949-50	154,000	89,300	94,600
51	218,000	146,800	139,100
52	245,000	164,300	162,400
53	253,000	181,400	184,000
54	225,000	153,100	148,500
1954-55	130,000	74,200	88,000
19-year average from 1933-34 through 1940-41 and from 1944-45 through 1954-55	175,100	117,100	113,200
35-year average from 1920-21 through 1954-55	162,300		108,700
Mean	171,000		111,800

TABLE 9

NATURAL, RECORDED HISTORIC, PRESENT IMPAIRED, AND ULTIMATE IMPAIRED SEASONAL RUNOFF OF KLAMATH RIVER AT COPCO FOR THE PERIOD 1920-21 THROUGH 1954-55 a/

(In thousands of acre-feet)

Season	Estimated natural runoff	Recorded historic runoff	Estimated present impaired runoff	Estimated ultimate impaired runoff c/
1920-21	1,911		1,867	874
22	1,587		1,344	796
23	1,381		1,131	581
24	1,155	1,000	805	428
1924-25	1,502	1,210	976	471
26	1,055	956	816	447
27	1,712	1,440	1,287	533
28	1,451	1,320	996	558
29	1,120	915 b/	795	495
1929-30	1,095	783 b/	706	472
31	860	527 b/	565	404
32	1,065	691 b/	633	466
33	1,050	699 b/	630	467
34	925	698 b/	595	416
1934-35	1,140	822 b/	705	470
36	1,301	1,084 b/	991	538
37	1,130	873 b/	766	492
38	1,812	1,727 b/	1,666	992
39	1,140	919 b/	806	527
1939-40	1,391	1,172 b/	1,144	700
41	1,231	967 b/	856	537
42	1,366	1,216 b/	1,136	716
43	2,018	1,895 b/	1,788	1,427
44	1,291	1,143 b/	989	734
1944-45	1,291	1,072 b/	970	549
46	1,592	1,329 b/	1,307	907
47	1,172	878 b/	885	554
48	1,294	981 b/		
49	1,338	1,074 b/		
1949-50	1,391	1,060 b/		
51	1,908	1,636 b/		
52	2,475	2,218 b/		
53	2,056	2,187 b/		
54	2,344	2,070 b/		
1954-55	1,310	1,081 b/		
27-year average from 1920-21 through 1946-47	1,324		1,006	613
32-year average from 1923-24 through 1954-55	1,406	1,176		
35-year average from 1920-21 through 1954-55	1,425			

a/ Based on data prepared for Bulletin No. 17.
b/ Because the gaging station of Klamath River at Copco was moved downstream in 1928 below the confluence with Fall Creek, these values were computed as the difference between the measured flow of the Klamath River below the confluence with Fall Creek and the measured flow of Fall Creek.
c/ Ultimate impaired runoff is defined as the flow of a stream, as it would have occurred historically, if at the time of historic record it had been altered by ultimate conditions of upstream development.

waters. Data on maximum floods of record, standard project flood, and maximum probable flood peaks are presented in Table 10.

TABLE 10

RECORDED AND ESTIMATED FLOOD FLOWS
AT SELECTED LOCATIONS ON SHASTA RIVER

Location	Peak discharge, in second-feet		
	Maximum historical flood during period of record	Standard project flood	Maximum probable flood
Dwinnell Reservoir	3,800 a/	12,800	21,400
Grenada Ranch Dam site	4,600 a/	16,600 c/	24,600 c/
Gregory Mountain Dam site	5,900 a/	27,700 d/	46,200 c,d/
Montague Dam site	6,000 a/	29,100 c,d/	48,500 c,d/
USGS Gaging Station, Shasta River near Yreka	6,090 b/	---	---

a/ Estimated on basis of USGS gaging station Shasta River near Yreka and/or Shasta River at Edgewood Bridge.
b/ Recorded flow partially regulated by Dwinnell Reservoir, December 27, 1955.
c/ Dwinnell Reservoir assumed full with all outlet and spillway gates fully open at beginning of flood.
d/ Grenada Ranch Reservoir assumed to be constructed and full to spillway lip at beginning of flood.

Ground Water

An investigation of the ground water resources of Shasta Valley was conducted by the Ground Water Branch of the United States Geological Survey, under cooperative agreement with the State of California during 1953 and 1954, in connection with the Klamath River Basin Investigation. A report on this investigation, "Geology and Ground Water Features of Shasta Valley, Siskiyou County, California", was published in 1960. The

purpose of the investigation was to obtain basic data relating to the extent, character, and thickness of the water-bearing strata; to determine the availability and quantity of ground water for beneficial purposes; to ascertain the geologic factors which control the occurrences and movement of ground; and to determine the chemical character of the ground water.

Ground water in Shasta Valley is discharged by both natural and artificial means. Natural discharge occurs by seepage into streams and by evapotranspiration (evaporation directly from the soil, and plant transpiration). Artificial discharge results from the pumping and flow of water from wells, which is small in relation to the volume of surface water diverted for various agricultural purposes. Most of the wells in Shasta Valley are dug wells about 20 feet deep, concentrated in the Gazelle-Grenada and Big Springs areas. Yreka has a municipally owned water system, but most of the smaller urban areas are served by either private water companies or individually owned wells. In 1953 about 5,500 acre-feet of ground water were pumped or drawn from wells in the area; during the same period an estimated 57,500 acre-feet of surface water was diverted and applied for irrigation. The 5,500 acre-feet represent gross pumpage; the net draft, or water permanently removed from the ground water reservoir, was probably about 4,000 acre-feet. The difference of 1,500 acre-feet represents the excess of applied irrigation water which percolated back to the water table. Although some new wells have been drilled since 1953, the ratio of water pumped from ground water to water diverted from surface flows has not increased significantly.

Although the geologic structures within the Shasta River Basin have quite different water-bearing characteristics, the ground water body

appears to have hydrologic continuity. The water-bearing rocks can be grouped into three categories; (1) basement rocks, (2) unconsolidated sediments, and (3) volcanic rocks.

The basement rocks on the west and northwest of the basin comprise all pretertiary units including the metamorphic, intrusive, and marine sedimentary rocks. These rocks are all relatively nonwater-bearing. However, water is usually present in faults and other fractures in sufficient quantities for domestic and stock-watering purposes, although in some localities it is not unusual to encounter a dry well.

The unconsolidated sediments generally may be divided into the Older and Recent deposits. The Older alluvium, which extends throughout the northern portion of the valley, yields very little water, primarily because of the large percentage of silt and clay. However, yields sufficient for domestic use and stock-watering purposes can usually be obtained. The Recent alluvium generally consists of beds of silt and clay with interlayered lenses of sand and gravel. Most of the wells tapping this younger alluvium are used for domestic and stock-watering supplies, although some wells located along the westerly portion of the valley obtain sufficient water for irrigation and municipal use.

A number of wells located in the southern portion of the valley, east of Edgewood, penetrate morainal and glacial outwash deposits and attain yields ranging from 600 to 1,500 gallons per minute, with an average of about 1,000 gallons per minute. However, the apparent lack of sorting, characteristic of the bulk of these deposits, is reflected by generally low permeability. Thus, it seems reasonable to assume that these wells produce ground water from the underlying Western Cascade volcanic rocks.

The Tertiary and Recent volcanic rocks are by far the best ground water producers in Shasta Valley. The Tertiary rocks of the Western Cascade series may be generally divided into lava flows, volcanic sediments, and volcanic necks and domes. Permeability of the Western Cascade rocks is somewhat variable, but permeability of the lava flows, which comprise most of the series, is generally high. This high permeability is the result of the interconnecting joints and fractures and the many small openings in the tops and bottoms of the individual flow units. Yields of irrigation wells which tap these lava flows in the Gazelle-Grenada area, range from about 120 to 1,400 gallons per minute with an average of about 500 gallons per minute. The permeability of the volcanic sediments interbedded with the lava flows varies greatly, depending on gradation and size of individual particles. In the northeastern portion of the valley these sediments are generally poor water producers. The volcanic necks and domes are limited in extent and are generally nonwater-bearing.

The Recent volcanic rocks, which cover an area of about 50 square miles in the southeasterly quarter of the valley, termed the Pluto's Cave basalt, yield the greatest quantity of water of any aquifer in Shasta Valley. This information, composed of many lava flows ranging in thickness from 5 to 10 feet each, is estimated to attain a cumulative thickness of 400 feet near its source at the base of Mount Shasta. To the northwest, in the vicinity of Big Springs, it thins to a thickness of about 100 feet.

Highly vesicular and clinkery basalt occurs at the top and bottom of the individual lava flows of this formation. Water is believed

to be transmitted along the vesicular contacts between the strata, through the interconnected fractures within the formation, and through debris-filled lava tubes where they occur below the water table. The most productive irrigation wells are found in the Big Springs-Four Corners area where the yield of wells tapping the Pluto's Cave basalt ranges from 100 to 4,000 gallons per minute, with an average yield of approximately 1,300 gallons per minute.

Table 11, taken from United States Geological Survey Water Supply Paper 1484, lists the various geologic units of Shasta Valley, with data on the thickness, general characteristics, and water-bearing properties of each.

The main source of ground water recharge in the Shasta River Basin stems from deep percolation of direct precipitation which falls on the tributary drainage area and flows toward the valley, where it percolates to ground water or appears as spring discharge. Recharge is also effected by seepage from streams and deep penetration of excess irrigation water.

Water Quality

Analyses of surface and ground waters of the Shasta River Basin show that the waters are generally of good to excellent mineral quality, suitable for most beneficial purposes.

In all activities dealing with measurement and observation of physical data, there must be a yardstick or standard by which the observer, planner, and user can classify and grade the information gathered. In judging water quality this yardstick is made up of empirical factors,

TABLE 11

Geologic units of Shasta Valley, California (With respect to ground water)*

	Age	Geologic unit	Thickness (feet)	General character	Water-bearing properties
Quaternary	Recent	Younger alluvium	0-140±	Unconsolidated stream-channel, flood-plain, and alluvial-fan deposits consisting of lenses of sand, gravel, and some clay.	Fairly permeable. Yield sufficient water for domestic and stock uses and locally along the west side of the valley for irrigation use. Gravelly deposits near Yreka Creek yield abundant water for municipal use to Yreka.
		Plutos Cave basalt	0-400±	Black vesicular olivine-rich augite basalt.	Constitutes the principal aquifer in Shasta Valley, yielding abundant water to irrigation, stock, and domestic wells in the vicinity of Big Springs. The amounts from irrigation wells vary considerably but average about 1,300 gpm.
	Recent to Pleistocene	Older alluvium	0-90±	Unconsolidated deposits consisting of poorly sorted boulders, gravel sand, and clay. Contains a persistent layer of hardpan about 1 foot thick which commonly is found 10-16 inches below land surface. Underlies much of the northern part of the valley in the vicinity of Montague.	Generally less permeable than the younger alluvium. Yields are small, but generally are sufficient for domestic and stock uses.
		Fluvioglacial and morainal deposits	0-300±	Unconsolidated materials ranging in size from clay to boulders, highly variable in permeability from place to place according to the proportion of fine materials to coarse.	Wide differences in permeability exist within relatively short distances. Irrigation wells tapping glacial deposits east of Edgewood yield 600-1,500 gpm.
	Pleistocene	Terrace deposits	0-50±	Unconsolidated; gravel and sandy clay along west side of valley.	Unimportant hydrologically because of rather limited extent and position generally above the water table.
	Recent to Pliocene	Volcanic rocks of the high Cascades		Lava flows, consisting mainly of olivine basalt and basaltic andesite.	Very permeable; important as a storage reservoir for much of the ground water that eventually finds its way into Shasta Valley. Springs issue near contact with underlying volcanic rocks of the western Cascades.
Tertiary	Miocene to Eocene	Volcanic rocks of the western Cascades	15,000±	Composed chiefly of andesitic lavas and pyroclastic ejecta and subordinate flows of basalt and dacite, beds of rhyolite tuff, and a few rhyolite domes.	Yields of wells vary greatly because of rapid changes in permeability both laterally and vertically. Supply sufficient water for domestic and stock uses. Yield abundant water for irrigation in Gazelle-Grenada area.
	Eocene	Umpqua formation	800-2,000	Sedimentary beds of fresh-water origin, consisting mainly of thin-bedded black shale and silty shale, although sandstone and conglomerate are present.	Yield is generally small. Locally yield sufficient water for domestic and stock uses.
Cretaceous	Late Cretaceous	Chico formation		Dominantly well bedded yellow to greenish-gray arkosic sandstone and graywacke. In the uppermost part of the formation, beds of black shale alternate with layers of sandstone.	Tapped by only a few wells in the area. Yields are generally small. Locally yields sufficient water for domestic and stock uses.
Cretaceous and older	Pre-Late Cretaceous	Basement complex (includes Abrams mica schist, Chanchelulla formation of Hinds (1931) and other rocks, undifferentiated)		Composes the bedrock along the western part of Shasta Valley. Consists of quartzitic schist; slightly metamorphosed sandstone, shale, and limestone; metavolcanic greenstone; and intrusive ultramafic and granitic rocks.	Tapped by only a few wells in the area. Yields are generally small, but structural openings such as joints, faults, shear zones, and openings along foliation planes locally transmit sufficient water for domestic and stock uses.

* From United States Geological Survey Water Supply Paper 1484, "Geology and Ground Water Features of Shasta Valley, Siskiyou County, California".

such as the experience and observations of many qualified persons who, at one time or another, have had occasion to determine with some degree of precision those water quality factors which are beneficial and those which are injurious for beneficial uses. It should be kept in mind that water which is injurious for one application is not necessarily so, or not to the same degree, for some other application. For instance, water that is totally unfit for human consumption may be entirely satisfactory for irrigation of certain crops on certain lands. Space in this bulletin does not permit a full discussion of all water quality criteria; however, as water use in the Shasta Valley is primarily for irrigation purposes, water quality was evaluated with respect to its suitability for that use.

Criteria for the mineral quality of irrigation water have been developed at the University of California at Davis and at the Regional Salinity Laboratory of the United States Department of Agriculture. These are shown in the following tabulation.

Qualitative Classification of Irrigation Waters

Chemical properties	Class I excellent to good	Class II good to injurious	Class III injurious to unsatisfactory
Specific electrical conductance, in microhms at 25° Centigrade	Less than 1,000	1,000-3,000	More than 3,000
Total dissolved solids, in ppm (parts per million)	Less than 700	700-2,000	More than 2,000
Chlorides, in ppm	Less than 175	175- 350	More than 350
Sodium, in percent of base constituents	Less than 60	60- 75	More than 75
Boron, in ppm	Less than 0.5	0.5- 2.0	More than 2.0

These criteria are subject to limitations in actual practice. In many instances a water may be wholly unsuitable for irrigation under certain conditions of use, and yet be satisfactory under other circumstances. Additional physical factors such as soil permeability, drainage, temperature, humidity, and rainfall, can materially alter the response of a crop to a particular quality of water.

Specific electrical conductance ($EC \times 10^6$), is a chemical property of a given water, which provides an approximate measure of the quantity of total dissolved solids in solutions containing mineral matter. This determination is simple and inexpensive, and the measured values of electrical conductance are a very useful index to the classification of water supplies.

Chlorides (Cl) are considered to be among the most troublesome chemical properties found in irrigation water supplies. In excess concentrations they are generally toxic to most plants and are an important consideration in classifying waters intended for use in irrigation.

For many years, leading agricultural experts have used the measure known as "percent sodium" (percent Na) to identify waters which might induce the undesirable characteristics associated with alkali soils. When irrigation water containing an excess of sodium is applied to soils, the soil could be impaired in both tilth and permeability.

While minute traces of boron (B) are essential for plant growth, many plants are very sensitive to boron and even small concentrations, barely in excess of the tolerance level, may produce plant injury.

General objectives of the collection of water quality data during this investigation were: (1) determination of quality of surface inflow

to, and outflow from, the Shasta River Basin; (2) determination of the effect of the quality of water on lands served; and (3) evaluation of factors affecting water quality. To these ends, discussion of the mineral quality of water supplies is divided into separate sections dealing with surface water, ground water, and water quality problems. Tabular data on water quality are generally arithmetical average values for the entire area under investigation. Detailed data concerning the quality of water supplies in this area are on file with the Department of Water Resources.

Quality of Surface Water

The quality of surface runoff in the Shasta River Basin is rather uniform throughout the basin. In the upper part of the valley the waters are magnesium bicarbonate in character, while in the lower reaches of the valley the magnesium concentration decreases and the waters become classed as calcium-magnesium bicarbonate. Samples of surface runoff were collected at points shown on Plate 3, "Locations of Water Quality Sampling Points". A summary of concentration of selected mineral constitutent of waters in the streams of Shasta Valley is presented in Table 12. Detailed chemical analyses of water obtained at surface sampling points located throughout the valley are on file with the Department of Water Resources.

TABLE 12

SUMMARY OF CONCENTRATIONS OF SELECTED MINERAL CONSTITUENTS IN SURFACE WATERS OF SHASTA VALLEY

Constituents	Range of values	Average values
Total dissolved solids, in ppm	62-588	257.00
Electrical conductance ($EC \times 10^6$ at 25°C)	69.7-959	388.00
Chloride, in ppm	0-27.	11.50
Boron, in ppm	0-2.4	0.35
Sodium, in percent of total cations	2-63	21.00
Hardness (as $CaCO_3$), in ppm	28-518	161.00

Water with average characteristics, such as those listed in Table 12, is considered to be Class I for irrigation purposes. The mineral quality of this water is satisfactory for domestic use although it is moderately high in hardness.

In traversing the length of the valley, the total dissolved solids content of the Shasta River increases. This is apparently due to the fact that some waters from tributary streams of the Shasta River contain higher concentrations of minerals than are contained in the river itself. It must not be supposed, however, that all streams contain such higher concentrations. The streams draining into the upper portions of the Shasta River are of excellent mineral quality.

Oregon Slough, Little Shasta River, and Willow and Julian Creeks are somewhat inferior in quality due to higher boron content. Oregon Slough and Little Shasta River contain water from springs rising near Table Rock, which have high concentrations of boron. During low flows, these springs constitute a larger percentage of total flow into the Shasta River, resulting in higher boron concentrations. The Little Shasta, near its mouth, has an average boron concentration of 1.08 ppm, which places it in the Class II category for irrigation purposes. Willow and Julian Creeks receive irrigation return water from an area irrigated with highly mineralized ground water of deep origin.

A number of small, land-locked lakes are situated in the south-central portion of the valley. These yield a sodium bicarbonate type water with concentrations of total dissolved solids and boron in excess of 950 ppm and 2.60 ppm, respectively. This high mineral content results from evaporation of water, leaving a residue with an increased concentration

of dissolved salts that renders the water unsuitable for irrigation purposes. Two factors operate to minimize the seriousness of this problem. First, the crops now being grown, or predicted for future cultivation, are for the most part, tolerant or semitolerant to observed concentrations of boron. Second, the total land area affected is small. The lakes are used, however, for nesting and resting areas by ducks and other waterfowl. It is assumed that no other beneficial use is to be made of them in the future.

Quality of Ground Water

Ground water in Shasta Valley is calcium-magnesium bicarbonate in character with total dissolved solids ranging widely, from 91 to 4,870 ppm. However, at the majority of the points sampled the total dissolved solids in the ground water ranged from 300 to 600 ppm. Wells yielding poorer quality water are generally found in rather limited areas, including the area along Oregon Slough and Little Shasta River, a small area at the lower portion of the valley near Montague and the central portion of the valley between the towns of Grenada and Big Springs. A summary of the extreme and average values of concentrations of selected mineral constituents in ground water samples of Shasta Valley is presented in Table 13. Detailed chemical analyses are on file at the Department of Water Resources.

TABLE 13

SUMMARY OF CONCENTRATIONS OF SELECTED MINERAL CONSTITUENTS IN GROUND WATER IN SHASTA VALLEY

Constituents	Range of values	Average values
Total dissolved solids, in ppm	91-4,870	479.00
Electrical conductance (EC x 10^6 at 25°C)	118-7,400	696.00
Chloride, in ppm	0.5-860	30.40
Boron, in ppm	0.00-14.00	0.61
Sodium, in percent of total cations	3-95	24.60
Hardness, as $CaCO_3$, in ppm	30-582	248.00

Water Quality Problems

Water quality problems in Shasta Valley are varied but appear to be relatively minor. Conditions which cause quality impairment problems of surface water are: (1) disposal of municipal waste; (2) irrigation return flow; (3) excess concentration of carbon dioxide; (4) adverse salt balance in small, closed drainage basins; and (5) algal growth. These conditions and related problems are considered in the following discussion.

Municipal sewage waste originating from small communities is a limited source of water quality impairment. However, suitable controls have prevented this condition from becoming a more serious water quality problem.

A minor problem exists in connection with the return flows of irrigation waters. During the irrigation season, a considerable quantity of return flow enters many of the streams in the valley and, in some cases, comprises the major part of the flow. The return water generally degrades the body of surface water, the degree of degradation depending upon the original composition of the surface flow and the quantity of mineral constituents absorbed per unit of irrigation return flow. This process is

repeated with each application of irrigation water and, although the quantity of minerals picked up during any one cycle is small, the aggregate may be sufficient to double the concentration of minerals in the downstream reaches of the Little Shasta, Shasta River, and Oregon Slough. In spite of this fact, the chemical properties of these waters are still within the limits of Class I irrigation water.

Big Springs Lake contains waters having concentrations of carbon dioxide in excess of 68 parts per million. Adverse effects of high concentrations of free carbon dioxide are: (1) formation of carbonic acid which is highly corrosive and, if used in domestic water systems, tends to accelerate the corrosion of iron and steel; (2) an increase of the solvent action on calcium carbonate in cement, which makes it a poor source of water for mixing concrete; and (3) inability of fresh water fish to live throughout the year in water with carbon dioxide in excess of 12 parts per million. This problem is confined to Big Springs Lake and its outflow, since carbon dioxide decreases to about 10 parts per million, or less, about one mile below the lake. The source or origin of carbon dioxide in water supplying Big Springs Lake has not been ascertained.

There is a very small amount of algal growth in the Big Springs Lake and in Dwinnell Reservoir, probably supported by the carbon dioxide in the waters. While growth of algae may be deleterious to various beneficial water uses and causes inconvenience in the operation of physical works, it is difficult to ascertain or establish limiting concentrations. Algae are often responsible for taste and odor in water supplies, as well as scum and discoloration, and foster increased growth of insect larvae

and water fleas. Algal growth may be influenced by many factors, such as acidity, turbidity, sunlight, temperature, rate of flow, and concentration of the various minerals, particularly phosphates, found in water. Decomposition of organic matter and drainage from farmlands serve to stimulate algal blooms.

The problems associated with quality of ground waters apparently stem from natural conditions. There is no indication that the poor quality ground water mentioned previously is a result of cultural development. Considerable faulting and other geologic activities have taken place in the valley in the past. During these activities highly mineralized magmatic waters may have been forced upward through faults and fissures and degraded the ground water in certain areas.

Table Rock Springs, located just south of Little Shasta River in the eastern edge of the valley, yields water with high concentrations of sodium, chloride, and boron. Concentrations of total dissolved solids and boron in water from these springs average about 4,700 and 14 parts per million, respectively. It is possible that water from Table Rock Springs originates at great depth, and that the high boron concentration may reflect recent volcanic activity, since this mineral is characteristic of springs in volcanic areas.

CHAPTER III. WATER UTILIZATION AND REQUIREMENTS

In recent years the Department of Water Resources has made extensive studies of land and water use and water requirements within the Shasta River Basin. The results of these studies were first published in a preliminary edition of Bulletin No. 58, "Northeastern Counties Investigation", December 1957, followed by final publication in June 1960. The revised data presented in the final publication of Bulletin No. 58 were published in more detail in Bulletin No. 83, "Klamath River Basin Investigation", May 1960. Since these data were of such recent date they were used for determinations of land and water use and water requirements for purposes of this investigation.

Present Water Supply Development

Water in the Shasta River Basin is developed and used mainly for irrigated agriculture and related purposes such as stock watering. The demand is partially met by means of direct diversions and surface water storage of the stream flow of the Shasta River and its tributaries. Ground water pumpage provides some of the demand for water. Organized water agencies provide water to about 28 percent of the presently irrigated land; the remaining 72 percent is served from developments of private individuals.

Water Service Agencies

Development of irrigation facilities in Shasta Valley began with the settlement of the area by miners in the early 1850's. This development was generally limited to areas easily served by gravity diversion of unregulated stream flow. In 1905, planning was initiated

by the United States Reclamation Service to import water from the Klamath River, but the proposed project was abandoned after preliminary study. Following this planning activity, local groups organized to improve and expand the then existing facilities. As a result of local actions over a period of years a mutual water company, three public irrigation districts, and various municipal water agencies were formed. These are described herein, and their service areas are shown on Plate 1.

Shasta River Water Users Association. The Shasta River Water Users Association is a mutual company, formed in 1912, for the purpose of serving water to lands located along the west side of the Shasta Valley near Montague. The area served embraces approximately 6,700 acres, of which about 6,000 are irrigable although only 2,800 are now being irrigated.

Water distributed by the association is obtained by pumping from the Shasta River near the town of Grenada in Section 3, Township 44 North, Range 6 West, MDB&M. The association has a water right established November 25, 1912, to 42 second-feet during the period from April 1 to October 1 of each year. Water is pumped from the river to a ditch about 80 feet higher than the river surface, and some of the water in the ditch is then pumped an additional 20 feet to a higher ditch. The lower ditch extends five miles to the north of the pumping plant, and about 3 miles to the south. The northern part of the ditch has a capacity of 18 second-feet and the southern part has a capacity of 10 second-feet. The upper ditch has a capacity of about 12 second-feet, and extends about three miles to the north and 2.5 miles to the south.

Grenada Irrigation District. The Grenada Irrigation District was organized in 1921 to serve the same area that had been previously served by the Lucerne Water Company. The service area, located west of Grenada, contains about 1,800 acres, of which about 1,500 acres are irrigable. About 1,000 acres are now being irrigated.

The water supply for the district is obtained by pumping from the Shasta River near Grenada in Section 6, Township 43 North, Range 5 West, MDB&M. The district has a decreed right[1/] to a 40 second-foot diversion during the period from April 1 to October 1 of each year. However, prior rights downstream from the point of diversion amount to about 80 second-feet and, in the past, this has prevented the district from receiving its full entitlement.

Water is diverted from the Shasta River by a small masonry dam, then conveyed about 1,000 feet in a lined canal to the district's pumping plant, where it is lifted 72 feet into the main canal, which extends westward about five miles. This canal is unlined and has serious seepage problems. At its terminus, part of the water is passed through a second pumping plant to be lifted 56 feet to an upper canal. The water remaining in the main canal is conveyed northward by an unlined canal which terminates in the vicinity of Grenada. The upper canal extends northward about 3.5 miles and southward about two miles from the pumping plant.

Montague Water Conservation District. Many attempts have been made by various individuals and private organizations to devise an economically feasible method of importing water from the Klamath River into

1/ Decree 7035 Superior Court, Siskiyou County, December 30, 1932.

Shasta Valley. The last such attempt was made in 1923 by the United States Reclamation Service (now the United States Bureau of Reclamation) which, like the others, was unsuccessful. The data gathered during these attempts did, however, provide the framework for formation of the Montague Water Conservation District and subsequent constructions of Dwinnell Dam and Reservoir.

The district was formed in 1925 by landowners, who agreed not to sell their lands for more than $75 per acre during the three-year period following organization of the district in order to discourage speculation and promote settlement of Shasta Valley. Dwinnell Dam and Reservoir are located in the east-central portion of Shasta Valley about midway between the towns of Big Springs and Weed. The reservoir has a total storage capacity of 72,000 acre-feet, but due to problems of seepage and structural stability of the dam storage was limited to 34,000 acre-feet. Since the construction of a berm on the downstream toe of the dam in 1956, the Department of Water Resources, State Supervision of Dams, changed the storage limitation to 50,000 acre-feet.

The district holds water rights for storage of 35,000 acre-feet of water from the Shasta River during the nonirrigation season each year, and 14,000 acre-feet of water from Parks Creek during the nonirrigation season. In addition, the district is entitled to about 20 second-feet during the irrigation season from tributaries of the Shasta River.

The district covers about 19,700 acres, of which about 15,600 acres are irrigable. About 6,000 acres are presently being irrigated. Water is conveyed by canal from Dwinnell Reservoir to the

Big Springs Lake in the Shasta Valley—Artesian Springs may be seen in the foreground.

service area that lies mainly in the vicinity of Montague. The main canal has a length of about 21 miles; the water is distributed by means of some 50 to 60 miles of lateral ditches.

Big Springs Irrigation District. The Big Springs Irrigation District was formed in June 1927, succeeding the Big Springs Water Company, which had been organized in 1913. In 1928 a bond election was passed to provide funds for repairs and improvement of facilities. After years of financial difficulties, the district is now operating profitably and has very little outstanding indebtedness.

The service area of the district is located to the north of Big Springs Lake, and contains a gross area of about 3,600 acres of which about 3,300 acres are irrigable. About 1,700 acres are being irrigated at the present time.

The water supply of the district is obtained mainly from Big Springs Lake in the vicinity of Four Corners in Section 3, Township 43 North, Range 5 West, MDB&M. The irrigation district has a water right for 30 second-feet from this source.

Water is pumped directly from Big Springs Lake into an unlined ditch about 55 feet above the lake's water surface, and is then conveyed about 4 miles to serve the lower lands in the service area. At a point about 1 mile from the main pumps, a second pumping plant lifts the water an additional 32 feet from the main ditch. A high-line unlined conduit, about 5 miles in length, approximately parallels the low-line ditch. In 1958 a well was drilled in the Pluto's Cave basalt in the vicinity of the second pumping plant making an additional eight second-feet of water available to the district.

Municipal Water Service Agencies. Until the winter of 1959, Yreka obtained its municipal water supply by pumping from wells that have a capacity of about two million gallons per day. Since this supply was insufficient to meet the needs of the present population of 4,500, action was initiated to develop a supplemental supply by the construction of a reservoir on Greenhorn Creek. It is estimated that, with the supply developed by Greenhorn Reservoir, it will be possible to supply water to meet the needs of a population of about 6,400, which it is estimated will be reached by about 1970.

Montague obtains a municipal water supply from the Montague Water Conservation District through the aforementioned conduit from Dwinnell Reservoir. The communities of Grenada and Gazelle obtain municipal water supplies from wells.

Land Use

Land use data were derived using aerial photographs as an aid to field surveys. The boundaries of various land use types segregated by irrigated crops, urban areas and other water using lands were delineated by field inspection on the aerial photographs. The boundaries were transferred to base maps and the areas were measured by means of the "cut and weigh" method.

The initial step in evaluating water requirements in the Shasta River Basins was to determine the nature and extent of present land use in relation to water use. Throughout the basin, with minor exceptions, the most recent available aerial photographs, at a scale of 1 to 20,000, were used in mapping. The areas devoted to various uses

and crop types were delineated on the photographs and transferred to base maps at a scale of 1 to 24,000, from which the acreage determinations were made. Determination of areas devoted to various uses and crops was made in terms of the gross included areas of water service. The gross areas were reduced by estimated percentages of included non-productive land, such as county and state highways, farm access roads, etc., in order to determine net (or actual) water service areas.

The present land use pattern in Shasta Valley consists of irrigated lands, urban lands, and swamp and marshlands. Irrigated lands were taken to include all agricultural lands dependent upon surface application of water, as well as those agricultural lands utilizing water from a high water table. Thus, subirrigated lands were included for each crop with the surface irrigated lands.

Irrigated Lands. Presently irrigated lands and boundaries of hydrographic units within the Shasta River Basin are shown on Plate 4, "Classification of Lands for Water Service". These lands include all agricultural areas which receive applied water from surface or ground water sources, or are irrigated through a ground water table which lies within the root zone of the crop under cultivation. The latter situation, which may be termed subirrigation, existed in some areas under natural conditions. In the spring, following a winter of normal runoff, the soil will have reached field saturation, that is, be unable to hold any more water. As the crops grow and the water is taken out of the soil through evapotranspiration, it may be necessary to apply water by means of small dams or diversion works. These works are designed to flood the fields by causing a stream or creek to overflow its natural course.

The irrigated crops, classified by field surveys during 1953, included alfalfa, pasture, hay and grain, clover, orchard, and potatoes and miscellaneous truck crops. Irrigated pastures were grouped in accordance with differences in water use. Improved pasture consists of land with improved irrigation facilities and is generally planted to selected grasses and legumes. Marginal pasture consists primarily of native grasses and plants from naturally distributed seeds. Meadow pasture consists of unimproved lands which sustain native grasses, including rush and wire grasses. Meadow pasture utilizes more water than improved pasture because of high-water table conditions. Pasture is the principal irrigated crop in the Shasta River Basin. Of the 37,250 acres presently irrigated within the basin, 13,900 acres are in improved pasture and 11,400 acres are in marginal and meadow pasture. The remaining 11,950 acres are devoted primarily to alfalfa and grain hay.

The estimated acreage of irrigated lands in hydrographic units of the Shasta River Basin during 1953 is presented in Table 14. The tabulated values are for the net irrigated areas after reduction for roads, farmsteads, and other nonwater-using areas.

Urban, Suburban, and Rural Lands. Present urban and suburban lands include the developed areas of the cities and towns, small communities, industrial areas, sawmills, and resorts of the Shasta River Basin. The lands comprise the gross developed area including homes, business districts, vacant lots, and industrial areas. The urban and suburban areas are not limited by municipal boundaries nor by any specific density of development. Miscellaneous areas utilizing water include

farmsteads, parks, golf courses, and cemeteries. The acreages of urban and suburban lands for each hydrographic unit in the Shasta River Basin during 1953 are tabulated in Table 14.

Reservoir and Swamp Areas. Dwinnell Reservoir, located in the Upper Shasta Hydrographic Unit, is the largest existing reservoir in the Shasta River Basin. It has a maximum water surface area of about 1,900 acres at the maximum allowable storage level. Under present conditions of operation it is estimated that the reservoir has an average water surface area of about 1,600 acres. In addition, there are numerous smaller reservoirs and farm ponds in the basin, which are estimated to have a total average water surface area of 400 acres.

Grass Lake, located in the easterly portion of the basin, in the Grass Lake Hydrographic Unit, constitutes a water using area of swamp and marshlands. It has an estimated average surface of about 1,300 acres.

Probable Ultimate Pattern of Land Use

Under ultimate development, it is probable that irrigated agriculture will continue to be the chief user of water in the Shasta River Basin. Therefore, considerable emphasis was placed upon determining the extent and classification of potentially irrigable lands and upon the forecast of the probable ultimate crop pattern. Consideration was also given to classification of irrigable lands better suited to timber production or forest management programs rather than to irrigated agriculture. Estimates were made of the areas that may be ultimately developed and utilized for urban and suburban purposes.

TABLE 14

PATTERN OF LAND USE WITHIN HYDROGRAPHIC UNITS OF SHASTA RIVER BASIN DURING 1953

(In acres)

Type of land use	Hydrographic unit							Totals
	Yreka	Little Shasta	Gazelle-Grenada	Big Springs-Juniper	Grass Lake	Parks Creek	Upper Shasta	
Irrigated Lands								
Alfalfa	210	5,920	3,200	900	0	160	260	10,650
Pasture								
Improved	40	2,990	2,990	2,160	0	2,760	2,950	13,890
Marginal	0	4,250	3,020	80	0	260	60	7,670
Meadow	20	360	1,120	1,050	310	400	470	3,730
Hay and grain	0	480	300	190	0	80	220	1,270
Clover	0	10	0	0	0	0	0	10
Orchard	0	10	0	0	0	0	0	10
Potatoes and truck crops	0	0	10	10	0	0	0	20
Net irrigated area	270	14,020	10,640	4,390	310	3,660	3,960	37,250
Streets and roads	10	730	560	230	20	200	200	1,950
GROSS IRRIGATED AREA	280	14,750	11,200	4,620	330	3,860	4,160	39,200
Urban, Suburban, and Rural Lands								
Cities, towns, and adjacent developed lands	610	100	110	0	0	0	630	1,450
Miscellaneous area*	70	500	220	90	10	80	110	1,080
GROSS URBAN AREA	680	600	330	90	10	80	740	2,530
GROSS AREA	960	15,350	11,530	4,710	340	3,940	4,900	41,730

* Miscellaneous water service areas include farmsteads, parks, golf courses, cemeteries, and industrial sites which are not within the cities, towns, and adjacent developed lands.

Irrigable Lands

Considerable emphasis was placed on the classification procedure and projection of probable ultimate crop pattern, since the water requirements for irrigated agriculture constitute the most significant portion of the ultimate water requirements within the Shasta River Basin. Estimated water requirements for irrigation purposes comprise more than 90 percent of the total water requirements of the basin.

Lands classified as suitable for irrigation development were segregated into three broad topographic groups; (1) smooth-lying valley lands, (2) slightly sloping and undulating lands, (3) steep and rolling lands. These three broad classes were subdivided into categories of adaptability for given crops. Factors affecting this subdivision included soil depths, rockiness, high-water tables, textures, moisture-holding capacities, salinity, and alkalinity.

In certain isolated portions of the Shasta River Basin, lands are found with soils and physical characteristics which would permit irrigation development but which are best suited to remain under some type of forest management. In general, these lands are located in the national forest areas, and it was assumed they would remain under forest management. They were not included in estimates of potential agricultural lands.

Lands in Shasta Valley had been classified during the Northeastern Counties and Klamath River Basin investigations with respect to their suitability for irrigated agriculture. As part of these investigations the location and extent of all irrigable lands

in Shasta Valley, and the immediately surrounding foothills, were determined by field surveys. All lands were grouped into their appropriate classifications of irrigability and crop adaptability. During these surveys considerable emphasis was placed upon the classification procedure and the projection of the ultimate crop pattern. Both of these considerations are significant in determining the water requirements to be used in water project planning studies, and the agricultural benefits to be used for the economic analysis of water projects.

The suitability of land for irrigation development is influenced by many factors. Topography, and physical characteristics such as texture, depth, and structure, directly affect the adaptability of the land for irrigation development. Further, the location of the land with respect to the available water supply affects the degree of possible development through irrigation. Some of the indirect factors are climatic conditions and the production and marketing of climatically adapted crops.

A summary of the results of the land classification is presented in Table 15, which shows the three general categories of irrigable lands, and other principal land use classes, by hydrographic units within the Shasta River Basin.

Even in the most intensively developed areas of irrigated agriculture, not all of the land is cultivated and not all irrigable lands are irrigated every year. Since the lands were classed in terms of gross acreage, it was necessary to determine the net acreage that might ultimately be irrigated in any one season. This determination depended upon one or more of the following factors: (1) quality of the land and crop rotation practices; (2) irrigable areas utilized for

TABLE 15

CLASSIFICATION OF IRRIGABLE LANDS
WITHIN HYDROGRAPHIC UNITS OF SHASTA RIVER BASIN

(In acres)

Hydrographic unit	Irrigable valley lands	Irrigable hill lands	Irrigable steep hill lands	Total irrigable lands	Lands best suited for forest management
Yreka	2,590	3,620	640	6,850	0
Little Shasta	38,710	11,590	240	50,540	890
Gazelle-Grenada	29,620	8,100	410	38,130	0
Big Springs-Juniper	17,540	1,590	270	19,400	0
Grass Lake	1,280	400	0	1,680	1,260
Parks Creek	8,040	1,890	120	10,050	0
Upper Shasta	8,920	4,810	240	13,970	950
Gross irrigable area	106,700	32,000	1,920	140,620	3,100

purposes other than agriculture; (3) exclusions of small nonirrigable areas within the irrigable areas; (4) size, shape, and location of irrigable land; and, (5) difficulty of development of irrigable lands with adverse topographic conditions.

Analysis of these factors showed that of the gross irrigable area of about 141,000 acres, the net irrigable area would amount to about 105,000 acres under ultimate development, if sufficient water supplies could be developed and applied to these lands.

The projection of a probable ultimate crop pattern that could be sustained on the net irrigable lands in the Shasta River Basin was an important step in evaluating ultimate water requirements. This projection took into account the development of agriculture throughout California, and the interactions of the local agricultural economy with that of the State as a whole. Other factors which will affect the ultimate crop pattern are climate and limitations on crop adaptability due to various land and soil characteristics. The county farm advisers and leaders in agriculture in the basin furnished additional information to aid in the forecast of future agricultural development. It was assumed that the present beef livestock economy would continue. For this reason, the crop projection was weighted heavily toward an increase in irrigated pasture and forage crops. The probable ultimate pattern of land use for each hydrographic unit within the Shasta River Basin, with a detailed breakdown of crops expected to be grown on irrigable lands, is presented in Table 16.

TABLE 16

PROJECTED ULTIMATE PATTERN OF LAND USE WITHIN HYDROGRAPHIC UNITS IN SHASTA RIVER BASIN

(In acres)

Type of land use	Hydrographic unit: Yreka	Little Shasta	Gazelle-Grenada	Big Springs-Juniper	Grass Lake	Parks Creek	Upper Shasta	Totals
Irrigable lands								
Alfalfa	2,200	16,700	12,200	6,100	800	1,700	4,200	43,900
Pasture								
Improved	1,300	8,900	6,500	4,300	600	3,100	2,600	27,300
Marginal	400	600	200	200	0	100	100	1,600
Meadow	0	2,000	3,700	1,000	0	1,800	1,700	10,200
Hay and Grain	900	6,200	4,500	1,800	0	300	1,300	15,000
Field crops	200	1,900	1,500	600	0	100	500	4,800
Truck crops	100	1,000	700	200	0	0	200	2,200
Net irrigable area	5,100	37,300	29,300	14,200	1,400	7,100	10,600	105,000
Right of way and non-productive area	1,750	13,240	8,830	5,200	280	2,950	3,370	35,620
GROSS IRRIGABLE AREA	6,850	50,540	38,130	19,400	1,680	10,050	13,970	140,620
Irrigable lands best suited for forest management	0	890	0	0	1,260	0	950	3,100
Urban and miscellaneous water service areas	1,100	1,400	700	300	0	100	1,100	4,700
Nonirrigable	32,950	72,870	59,270	95,200	15,060	22,850	61,780	358,980
TOTALS	39,900	125,700	98,100	114,900	18,000	33,000	77,800	507,400

Urban and Suburban Lands. Present and ultimate urban and suburban water requirements were determined on a population basis. The land areas expected to become predominantly urban and suburban were determined by Pacific Planning and Research, consultants in planning and urban economics, under a contract with the Department of Water Resources. This forecast is included in Table 16.

Recreational Lands and Uses. Dwinnell Reservoir is the only large body of water in the Shasta River Basin, and, although it is open to public use, it has few developed recreational facilities. However, limited facilities are available for stream and lake fishing; deer, waterfowl, and upland game hunting; and water sports on the Shasta River and Lake Dwinnell. Private lands and farm ponds within the basin provide some recreational facilities.

An investigation of the estimated ultimate recreational demand, which would determine the rate of recreational development, was made as part of the Northeast Counties Investigation, and reported in Department of Water Resources Bulletin No. 58. In that bulletin the term "Shasta Valley Hydrographic Area" is used to describe the same area denoted in this report by the term "Shasta River Basin".

It was estimated that the rate of increase of recreational usage of the basin would be much higher than its rate of population growth. Estimated potential ultimate recreational areas were delineated and classified into those areas of high, medium and low potentials in terms of user-days per year.

High intensity recreational use includes lands of prime recreational potential which are accessible by motor vehicle during the

Trout catch.

Recreotion—Dwinnell Reservoir.

entire vacation season. Most of the future development is expected to occur in these areas. Medium intensity recreational use includes lands of prime recreational value which are not readily accessible by motor vehicles. These areas will be developed to some extent, but their greatest use will probably be for fishing, hunting, hiking, camping, and similar recreational activities. Low intensity recreational areas are lands generally of inferior scenic and topographic qualities, although they may be important for hunting.

Analysis indicated that about 258,000 acres would ultimately be devoted to recreational uses in the Shasta River Basin. Of about this area 60,000 acres would be of high intensity, about 27,000 acres would be of medium intensity, and 171,000 acres would have a low intensity usage.

Forest Lands and Uses. Estimates of areas of commercial forest land and production of timber products were used to compute water requirements for the forest products industry. The processing and milling of timber products plays a more significant role in the timber industry in the Shasta River Basin than does the relatively small, sustained yield from present stands. The State Division of Forestry provided information upon which the water requirements relative to forest areas and forest products were based.

Reservoir and Swamp Areas. The estimated ultimate maximum and average reservoir water surface area within the Shasta River Basin, resulting from existing reservoirs and from the possible future Montague and Grenada Ranch projects, shown in Bulletin No. 3 "The California Water Plan",

is about 5,700 and 4,300 acres, respectively. In addition to these large water surface areas, there would be numerous smaller reservoirs and farm ponds, resulting in a total ultimate average water surface area in the basin of about 5,600 acres.

It was assumed that the present Grass Lake swamp and marshlands would remain unchanged under ultimate conditions because of their importance to waterfowl.

Population

Water requirements for present and probable ultimate urban and suburban areas were determined on the basis of present and probable ultimate populations of the Shasta River Basin. At present the basin is only moderately populated containing about one-third of the population of Siskiyou County. The U. S. 1960 census reported the county population to be 32,885 persons. Siskiyou County has not experienced the phenomenal population explosion that has characterized many areas of California; nevertheless, population in the county, as well as that of the Shasta River Basin, is expected to increase many times as California approaches full development. At present, about 90 percent of the people are concentrated in cities, towns, and adjacent developed areas.

Determination of present water requirements for urban and domestic uses was based upon present (1953) estimates of population made during the Klamath River Basin Investigation. The population of the Shasta River Basin at that time was estimated to be 12,050. The 1960 U. S. Census reported a population, for the entire basin, of 12,900 or an increase of 850 persons. Although not broken down directly, the 1960 census figures indicated that most of the increase had taken place in the Yreka area, and that the populations of smaller towns in the basin had decreased during the same period of time.

The present urban population of the Shasta River Basin is centered primarily in the City of Yreka and the town of Weed. These towns serve as shopping centers for the agricultural population and as industrial centers for the timber industries. There are a number of towns and communities such as Montague, Grenada, Gazelle, and Edgewood which have populations of only a few hundred. A summary of estimates of the 1953 population, for each of the hydrographic units within the Shasta River Basin, is shown in Table 17.

To determine the magnitude of the ultimate population that may be expected in the Shasta River Basin the State's future population, estimated to be 56,000,000 in the year 2020, was distributed among the geographic regions of the State by analyzing, for each region, historic growth trends, patterns of economic development, relative advantages for urban growth, net areas of vacant habitable lands, and expected changes in urban and suburban development. The resultant future population estimate for the Shasta River Basin for the year 2020 was about 49,000. These estimates exceed those previously published in Bulletins Nos. 58 and 83, in both of which the ultimate populations were predicted upon an estimated ultimate state population of 45,000,000. A summary of the estimated 2020 population for each of the hydrographic units within the Shasta River Basin is shown in Table 17.

Water Requirements

The estimated total water requirements for irrigated agriculture, urban, suburban, industrial, and recreational uses were used as a basis for planning future water development projects. The term "requirement" is a general term that expresses need for beneficial use of water, and it is customary that it be used with certain modifying words that define

TABLE 17

ESTIMATED 1953 AND PROJECTED 2020 POPULATIONS WITHIN HYDROGRAPHIC UNITS OF THE SHASTA RIVER BASIN

Hydrographic unit		1953 population			2020 population		
Reference designation	Name	Urban and suburban	Rural	Total	Urban and suburban	Rural	Total
A	Yreka	5,500	a/	5,500	20,000	370	20,370
B	Little Shasta	700	350	1,050	3,500	1,190	4,690
C	Gazelle-Grenada	600	350	950	500	920	1,420
D	Big Springs-Juniper	a/	150	150	a/	1,080	1,080
E	Grass Lake	50	a/	50	a/	160	160
F	Parks Creek	a/	50	50	a/	310	310
G	Upper Shasta	4,250	50	4,300	20,000	720	20,720
	TOTALS	11,100	950	12,050	44,000	4,750	48,750

a/ Indicates less than 50 persons.

the exact nature of the requirement. For example, "diversion requirement" is the amount of water needed at the point of diversion on a stream system to provide for losses in conveyance of water to places of use, for the necessary irrigation head to distribute the water in the fields, for the wetting of the soil volume, and for deep percolation, taking into account the reuse of return flows from irrigation or other employments of the water. Water requirements presented herein refer to "service area requirement"

that account for all the various uses of water in a specified area, measured at the point or points of entrance of the water into the area.

Only a part of the water which is applied to irrigated land is lost to the basin through transpiration by crops and evaporation from the land surfaces. These two types of losses, known as "consumptive use", are the only actual physical losses to the total quantity of water. For convenience, similar physical losses caused by other employments of water are also termed "consumptive use", although they may be entirely evaporative in character, such as losses from reservoir surfaces.

Nonconsumptive requirements refer to the use of water for fish propagation, power production, or for aesthetic purposes in which the water is put to beneficial use and then returned to the natural channels. In most instances the regimen of stream flow is changed but not the quantity or quality of the water.

Unit Values of Water Use

Unit values of water use for irrigated lands refer to the consumptive use of applied water by plants and the adjacent soil, expressed in feet of depth or, where convenient, in acre-feet. A unit value may also be thought of as a volume in terms of acre-feet per acre. The consumptive use of applied water was computed by multiplying the acreage of land involved by the unit value of water use.

Ideally, unit values of water use for irrigated agriculture, urban areas, industrial production, and recreation development are based upon measured values. Such data should be measured within the area under consideration to reflect the varying climatic and operational influences, and the measurements should be over a long enough period of time to reflect variations from year to year. In the absence of adequate data,

it is necessary to use available data from which to derive unit values of water for various crops and other land uses.

During the Shasta Valley Investigation all available water use data were tabulated and analyzed.

Data were collected within the Shasta River Basin, and from other areas in northern California, pertaining to water use on irrigated lands in urban and suburban areas. Similar data were collected for the forest products industry, recreation activities, and evaporation from reservoir surfaces. Mean seasonal unit values were then estimated for each of these types of water use.

Unit values of consumptive use of water by irrigated crops were determined from the results of soil moisture depletion studies conducted on representative irrigated plots in Shasta Valley during the growing seasons of 1953 and 1954, correlated by an empirical relationship with climatological data. Another series of soil moisture depletion studies was conducted on nonirrigated crops, fallow land, and native vegetation, for the purpose of evaluating effective precipitation.

Unit values of consumptive use of water by swamp and marshlands were derived from available pan evaporation records. Timber processing industries unit values were obtained from records of actual use by private lumber and wood products companies and from data developed by the United States Forest Service. Unit values of consumptive use of water by recreational facilities in the forested areas, and by other miscellaneous developments were in most instances estimated in terms of per capita use, based upon applicable information from all available sources. Records of total water delivery to urban areas were reduced to per capita consumption values.

Typical Meadow Pasture.

The basic procedure for estimating unit values of consumptive use of water by irrigated crops in the Shasta River Basin made use of the method evolved by Harry F. Blaney and Wayne D. Criddle, of the Soil Conservation Service of the United States Department of Agriculture, presented in their report "Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data", August 1950. A description of the method as stated in that report follows:

> Briefly, the procedure is to correlate existing consumptive use data with monthly temperature, monthly percentages of yearly daytime hours, precipitation, and growing or irrigation season use. Coefficients have been developed from existing measured consumptive use and temperature data and monthly percents of yearly daytime hours. Thus, if only monthly temperature records are available and latitude is known, the consumptive use can be computed from the formula U = KF: where U equals consumptive use of water in inches for any period, K = empirical consumptive use coefficient, and F = sum of the monthly consumptive use factors for the period (sum of the products of mean monthly temperature and monthly percent of annual daytime hours).

This procedure was used to determine soil moisture depletion values for different crops and areas within the Shasta River Basin. For those crops not covered by the plot studies, the results of appropriate studies in other areas were utilized. The studies included determinations of consumptive use of water for perennial crops during the nongrowing season, and for bare ground or stubble.

The portion of the unit seasonal value of consumptive use of water supplied by precipitation, referred to as "effective precipitation", was measured for each hydrographic unit. Moisture stored in the soil during the nongrowing season and utilized during the following growing season does not subsequently appear as runoff.

Unit values of consumptive use of applied water for each irrigated crop were then derived as the difference between total seasonal

consumptive use of water and effective precipitation. Estimated mean seasonal unit values of consumptive use of applied water on various irrigated lands are presented in Table 18.

TABLE 18

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER FOR THE SHASTA RIVER BASIN

(In feet of depth)

Type of land use	Estimated mean seasonal consumptive use		
	Of applied water	Of precipitation	Total
Irrigated crops			
Alfalfa	1.9	1.1	3.0
Pasture			
Improved	2.1	1.0	3.1
Marginal	1.6	1.0	2.6
Meadow	2.6	1.0	3.6
Hay and grain	0.6	1.0	1.6
Clover	1.6	1.0	2.6
Orchard	1.4	1.1	2.5
Potatoes and truck crops	0.9	0.9	1.8
Field crops	0.9	1.0	1.9

Estimates of unit values of water use for present and probable ultimate urban and suburban areas were determined on a per capita basis rather than on a unit area basis. The average daily rate of water used per capita was computed from records of water delivery and water consumption in towns in and near the Shasta River Basin for which water supply records

were available. It was estimated that the present water delivery requirement is about 200 gallons per capita per day for urban and suburban areas. Urban and suburban water requirements under ultimate development were also assumed to be about 200 gallons per day, delivered at points of use. Irrecoverable losses were estimated as 50 percent of the delivery requirement. It was anticipated that sewage outflow and other losses would not generally be available for direct re-use. Therefore, the consumptive use was assumed to be equivalent to the water requirement.

Separate estimates were made of potential water use by the forest products industry, since they are expected to be a significant quantity in the total urban demand, but are not generally included in estimates of urban water requirements. Unit values of water use for manufacture of forest products, mainly dimensioned lumber and plywood, were obtained from information made available by the United States Forest Service and various private companies.

Recreational activities were included in the ultimate consumptive use and requirements for water in the Shasta River Basin. Such activities include permanent and summer residences, commercial resorts and motels, organizational camps, and camping and picnic area. The unit values of water for these uses were largely estimated from experience and judgment.

Unit values of net reservoir evaporation were computed as reservoir surface evaporation in excess of precipitation during those months when monthly evaporation will be greater than precipitation. Net reservoir evaporation represents the quantity of water that is lost to use, over and above the amount of water previously consumed on the lands in the reservoir before construction. Seasonal unit values were based on records of

evaporation pans and atmometers maintained in Shasta Valley. Net seasonal depth of evaporation from reservoir surfaces was found to be about 2.0 feet in the Shasta River Basin.

Consumptive Use of Applied Water

Estimates were made of the amount of water consumptively used under present and probable ultimate conditions. In general, these estimates were derived by applying the appropriate unit values of water use to the present and estimated ultimate patterns of land use.

Present Use of Applied Water. Unit values of consumptive use of applied water for irrigated crops were determined on the basis of a full water supply, sufficient to meet the optimum moisture needs of the crop.

The amount of consumptive use of water in urban and suburban developments was estimated as the product of population for each category and the appropriate derived value of per capita consumptive use of water. The estimate of consumptive use for present urban and suburban developments also includes the water used for present industrial and recreational purposes, as well as the forest products industry.

To derive consumptive use from reservoir water surfaces, average areas of such surfaces, for each of the hydrographic units, were multiplied by unit net seasonal depth of evaporation from these surfaces.

The present mean seasonal consumptive use of applied water in the Shasta River Basin, as shown in Table 19, was estimated to be 85,100 acre-feet. This estimate represents consumptive use on the basis of a full water supply delivered to all irrigated lands. However, records maintained by

state watermasters show that in many areas of the basin full seasonal water supplies are not presently available and crops are subject to a deficient irrigation supply during summer and fall months. This applies particularly to pasture and alfalfa crops which require irrigation at frequent intervals throughout the summer and fall. Therefore, the average consumptive use, under present conditions, is somewhat less than the optimum consumptive use under a full water supply. Watermaster records, as well as the experience of watermasters familiar with local irrigation practices, indicate that forage crops receive about 70 percent of the optimum supply. As a result, the present consumptive use of applied water for all used in the Shasta River Basin, based on a deficient water supply, was estimated to be about 69,300 acre-feet per season as shown in Table 20.

Probable Ultimate Consumptive Use of Applied Water. The procedures utilized to estimate probable ultimate consumptive use of applied water were similar to those employed to estimate present consumptive use. The amount of water that would be used on lands ultimately irrigated was estimated by multiplying the projected ultimate acreage of each crop type by its respective unit value of consumptive use of applied water. Probable ultimate seasonal consumptive use of water by urban and suburban lands, recreational areas, and the forest products industry and by evaporation from principal reservoirs was estimated as the product of the forecast level of development times each applicable unit value of water use.

Estimates of ultimate consumptive use of applied water for irrigated lands were based on the assumption that a full seasonal water

TABLE 19

ESTIMATED PRESENT MEAN SEASONAL CONSUMPTIVE USE
OF APPLIED WATER IN THE SHASTA RIVER BASIN
WITH DELIVERY OF FULL WATER SUPPLY

(In acre-feet)

Hydrographic unit: Reference designation	Hydrographic unit: Name	Irrigated lands	Urban and suburban lands	Net reservoir evaporation	Swamp and marsh lands	Totals
A	Yreka	500	1,300	100	0	1,900
B	Little Shasta	25,600	600	300	0	26,500
C	Gazelle-Grenada	20,300	300	600	0	21,200
D	Big Springs-Juniper	9,200	100	300	0	9,600
E	Grass Lake	800	0	---*	3,700	4,500
F	Parks Creek	7,600	100	---*	0	7,700
G	Upper Shasta	8,100	1,000	4,600	0	13,700
	Totals	72,100	3,400	5,900	3,700	85,100

* Negligible.

TABLE 20

ESTIMATED PRESENT MEAN SEASONAL CONSUMPTIVE USE
OF APPLIED WATER IN THE SHASTA RIVER BASIN
BASED ON EXISTING DEFICIENT WATER SUPPLY

Hydrographic unit: Reference designation	Hydrographic unit: Name	Irrigated lands	Urban and suburban lands	Net reservoir evaporation	Swamp and marsh lands	Totals
A	Yreka	400	1,300	100	0	1,800
B	Little Shasta	20,700	600	300	0	21,600
C	Gazelle-Grenada	16,200	300	600	0	17,100
D	Big Springs-Juniper	6,700	100	300	0	7,100
E	Grass Lake	600	0		3,700	4,300
F	Parks Creek	5,700	100		0	5,800
G	Upper Shasta	6,000	1,000	4,600	0	11,600
	Totals	56,300	3,400	5,900	3,700	69,300

supply would be available for the net projected crop acreage assumed to be irrigated in any one season under ultimate conditions of development.

Consumptive use of applied water for urban and suburban purposes was computed as the product of the appropriate estimated population by the unit value of per capita water use. The probable ultimate consumptive use for the forest products industry was estimated as the product of the estimated annual production of lumber and plywood that would ultimately be processed on a sustained yield basis by the appropriate average unit value of water consumed in processing.

The probable ultimate consumptive use of applied water for recreational purposes was determined by multiplying the estimated user-days for each type of use in the recreation areas by the appropriate unit value of per capita water use. The totals were then expressed in acre-feet per season for each hydrographic unit.

The amount of evaporation from reservoir surfaces, under probable ultimate conditions of development, was estimated as the product of the water surface area in acres, at average operating levels, and the net unit values of seasonal evaporation from reservoir water surfaces. The total seasonal value includes evaporation from existing reservoirs, the proposed reservoirs shown in The California Water Plan, and several smaller reservoirs considered in this investigation. The estimated amount of evaporation from reservoir water surfaces under probable ultimate conditions of development would be approximately six percent of the total probable ultimate consumptive use in the Shasta River Basin.

Estimates of probable ultimate mean seasonal consumptive use of applied water are presented in Table 21.

TABLE 21

PROBABLE ULTIMATE MEAN SEASONAL CONSUMPTIVE
USE OF APPLIED WATER IN THE SHASTA RIVER BASIN

Hydrographic unit: Reference designation	Hydrographic unit: Name	Irrigable lands	Urban, suburban, industrial, and recreational lands	Net reservoir evaporation	Swamp and marsh lands	Totals
A	Yreka	8,400	3,300	100	0	11,800
B	Little Shasta	62,900	1,500	6,200	0	70,600
C	Gazelle-Grenada	51,600	1,100	3,000	0	55,700
D	Big Springs-Juniper	25,300	500	300	0	26,100
E	Grass Lake	2,800	100	0	3,700	6,600
F	Parks Creek	14,800	200	0	0	15,000
G	Upper Shasta	19,600	4,700	4,600	0	28,900
	TOTALS	185,400	11,400	14,200	3,700	214,700

Present and Probable Ultimate Water Requirements

A determination was made of the present and probable ultimate requirements for water in the area under investigation. These estimates represent the gross amount of water required to meet both demands for consumptive use of applied water and irrecoverable losses incidental to its application. Consideration was given to both farm irrigation efficiencies and the re-use of return flow. These estimates are the measure of the required water supply that presently and ultimately would be required on a firm basis for the particular hydrographic unit. In general, the estimates of water requirements were derived by dividing the consumptive use of applied water by an appropriate water service area efficienty factor for the particular hydrographic unit being considered.

The various water requirements were considered and evaluated for the general categories of irrigated agriculture; urban, suburban, and domestic populations; the forest products industry; recreation uses; and evaporation from reservoir areas.

Estimates of present mean seasonal water use with the presently available water supply are shown in Table 22. The quantities shown are based upon the assumption that alfalfa and pasture crops receive, at present, about 70 percent of a full irrigation demand. Table 23 shows estimates of potential present water requirements assuming a full water supply, delivered to all points of use.

Estimates of probable ultimate mean seasonal water requirements, shown in Table 24, are predicated upon the availability of a full water supply, delivered to all irrigable lands within the Shasta River Basin.

Requirements for Fish and Wildlife

In recognition of the importance of the Shasta River fishery resources, the Department of Water Resources entered into an agreement with the Department of Fish and Game for the purpose of determining the effect that potential reservoirs on the Shasta River would have on the fishery resources. The results of this fishery study are presented in Appendix B, "Preliminary Report on Fish and Wildlife in Relation to Plans for Water Supply Development in Shasta Valley". As noted in this appendix, the proposed reservoirs would eliminate large portions of the natural spawning and nursery areas used by king salmon, silver salmon, and steelhead, and would also tend to reduce the stream flow presently available for fish life. Consequently, the various fishery maintenance plans discussed by the

TABLE 22

PRESENT MEAN SEASONAL WATER UTILIZATION IN THE SHASTA RIVER BASIN, WITH AVAILABLE WATER SUPPLY

(In acre-feet)

Hydrographic unit: Reference designation	Hydrographic unit: Name	Irrigable lands	Urban, suburban, industrial, and recreational lands	Net reservoir evaporation	Swamp and marsh lands	Totals
A	Yreka	900	1,300	100	0	2,300
B	Little Shasta	24,900	600	300	0	25,800
C	Gazelle-Grenada	19,900	300	600	0	20,800
D	Big Springs-Juniper	9,100	100	300	0	9,500
E	Grass Lake	600	0	0	3,700	4,300
F	Parks Creek	6,500	100	0	0	6,600
G	Upper Shasta	7,000	1,000	4,600	0	12,600
	TOTALS	68,900	3,400	5,900	3,700	81,900

TABLE 23

POTENTIAL PRESENT MEAN SEASONAL WATER REQUIREMENTS IN THE SHASTA RIVER BASIN WITH A FULL WATER SUPPLY

(In acre-feet)

Hydrographic unit: Reference designation	Hydrographic unit: Name	Irrigable lands	Urban, suburban, industrial, and recreational lands	Net reservoir evaporation	Swamp and marsh lands	Totals
A	Yreka	1,000	1,300	100	0	2,400
B	Little Shasta	31,000	600	300	0	31,900
C	Gazelle-Grenada	26,100	300	600	0	27,000
D	Big Springs-Juniper	14,000	100	300	0	14,400
E	Grass Lake	800	0	0	3,700	4,500
F	Parks Creek	9,800	100	0	0	9,900
G	Upper Shasta	10,800	1,000	4,600	0	16,400
	TOTALS	93,500	3,400	5,900	3,700	106,500

TABLE 24

PROBABLE ULTIMATE MEAN SEASONAL WATER REQUIREMENTS
IN THE SHASTA RIVER BASIN WITH A FULL WATER SUPPLY

(In acre-feet)

Hydrographic unit: Reference designation	Name	Irrigable lands	Urban, suburban, industrial, and recreational lands	Net reservoir evaporation	Swamp and marsh lands	Totals
A	Yreka	16,700	7,300	100	0	24,100
B	Little Shasta	98,800	1,500	6,200	0	104,500
C	Gazelle-Grenada	103,000	1,100	3,000	0	107,100
D	Big Springs-Juniper	50,800	500	300	0	51,600
E	Grass Lake	5,600	200	0	3,700	9,400
F	Parks Creek	29,700	300	0	0	29,900
G	Upper Shasta	39,200	10,500	4,600	0	54,300
	TOTALS	341,800	21,400	14,200	3,700	380,900

Department of Fish and Game (in Appendix B) would require substantial stream flow maintenance releases together with artificial propagation facilities. The smaller the maintenance flows, the larger and more costly would be the artificial propagation facilities to maintain the present fishery.

Recommended maintenance flows represent the desired flow immediately above the confluence of the Shasta River and Yreka Creek. These flows are based on the biological needs of the fish species involved and represent the minimum quantities of water necessary to keep the fish in good condition and satisfy spawning requirements. The schedule of flows does not necessarily take into account the practical and economic considerations of supplying water on a firm basis. In recognition of this fact the Department of Fish

and Game included a dry-year clause designed to take into account the availability of water. Therefore, in formulating plans for water supply development, both the biological needs of the fish and the availability of water were taken into consideration.

Supplemental Water Requirements

The data, analyses, and estimates of water supply and water utilization presented in this report indicate that there are present and ultimate supplemental requirements for water in the Shasta River Basin. Estimates of supplemental water requirements were related to the development of new irrigated land, industries, urban areas, and other beneficial purposes as discussed previously in this chapter. These requirements represent the additional amount of water needed to provide a full water supply to all irrigable lands.

The present supplemental requirement is primarily the result of a deficiency in late summer and fall irrigation supplies. Agriculture in Shasta Valley has been adapted to crops and practices which do not suffer economic loss due to water shortages in the late growing season. However, in considering amounts of ultimate supplemental water needed, provision must be made to meet the present deficiencies.

It was previously stated that Watermaster Service records indicate that pasture and alfalfa crops in Shasta Valley normally receive about 70 percent of their full seasonal water demand. As a result, actual consumptive use of applied water is estimated to be about 69,000 acre-feet per season, whereas if a full supply were available consumptive use of applied water would be about 85,000 acre-feet per season. Similarly, the present water

requirement, based on available water supplies, amounts to about 82,000 acre-feet per season while the potential present water requirements, based on a full water supply, would be about 107,000 acre-feet per season. These estimates indicate that there is a present supplemental water requirement in the Shasta River Basin for about 25,000 acre-feet per season. Development of this amount of water and delivery to lands presently irrigated would provide a full seasonal supply.

Probable ultimate mean seasonal total water requirements for the Shasta River Basin were estimated to be about 381,000 acre-feet per season. Since only approximately 82,000 acre-feet per season are presently available, 299,000 acre-feet will be needed to fully satisfy the probable ultimate requirement. The amount of 299,000 acre-feet would include the 25,000 acre-feet needed to meet the present deficiency in water supply. Estimates of present and probable ultimate supplemental water requirements are shown in Table 25 for each hydrographic unit in the Shasta River Basin.

TABLE 25

ESTIMATED PRESENT AND PROJECTED ULTIMATE MEAN SEASONAL
SUPPLEMENTAL WATER REQUIREMENTS IN THE SHASTA RIVER BASIN

(In acre-feet)

Hydrographic unit		Present water requirement with available water supply	Present water requirement with full water supply	Present supplemental water requirement	Probable ultimate water requirement	Increase in water requirements from present with full supply to ultimate	Ultimate supplemental water requirement
Reference designation	Name						
A	Yreka	2,300	2,400	100	24,100	21,700	21,800
B	Little Shasta	25,800	31,900	6,100	104,500	72,600	78,700
C	Gazelle-Grenada	20,800	27,000	6,200	107,100	80,100	86,300
D	Big Springs-Juniper	9,500	14,400	4,900	51,600	37,200	42,100
E	Grass Lake	4,300	4,500	200	9,400	4,900	5,100
F	Parks Creek	6,600	9,900	3,300	29,900	20,000	23,300
G	Upper Shasta	12,600	16,400	3,800	54,300	37,900	41,700
	Totals	81,900	106,500	24,600	380,900	274,400	299,000

CHAPTER IV. PLANS FOR WATER SUPPLY DEVELOPMENT

Runoff from the Shasta River and its tributaries is subject to side monthly and seasonal variations. In years of low water supply, presently irrigated agricultural production must be curtailed. In order to meet the need for water during dry years, provide for expansion of irrigated agriculture, and meet growing municipal and domestic demands, additional water supplies must be developed.

Surface outflow from the Shasta River Basin, measured at Shasta River near Yreka, amounting to an estimated 108,700 acre-feet per season for the base period of this investigation, indicates that water supplies are available for development in Shasta Valley. Not all of this outflow can be conserved, because of excessive costs for storage and required stream flow maintenance for fish.

In Chapter III it was shown that a present supplemental supply of 25,000 acre-feet per season would be needed to provide a full supply to all lands presently irrigated in Shasta Valley. In addition, about 274,000 acre-feet per season would be required to provide water to irrigable lands presently without a water supply. Thus, the total ultimate supplemental water requirement for Shasta Valley is about 299,000 acre-feet per season.

Even with maximum conservation of the water resources of the Shasta River, the yield obtained would be far less than the estimated ultimate supplemental water requirements of Shasta Valley. Full satisfaction of those requirements will necessitate importation of water supplies from sources outside the basin.

Preliminary plans for developing the water resources of the Shasta River Basin, and for importing water to Shasta Valley are discussed in this chapter. Project costs reported herein are based on approximate quantities, estimated from preliminary designs, and on estimated unit prices based on recent bids on projects similar to those under consideration, and on manufacturer's price lists. The costs are considered to be representative of those prevailing in the spring and summer of 1959.

Estimates of total capital costs include costs of construction, stream diversion during construction, acquisition of lands, easements, and rights of way, and relocation of existing utilities and highways. The estimates include an additional allowance of 30 percent of capital costs for engineering, administration, and contingencies. Interest during the construction period is also included as part of the total capital cost. Estimates of average annual project costs include interest on the capital investment at four percent per annum, amortization over a 50-year period, operation costs, maintenance costs, and costs of electric energy required for pumping.

Estimates of project benefits presented herein include only the tangible benefits which may be measured in monetary terms, of significant magnitude to warrant their inclusion. These include benefits derived from the sale and use of project water for irrigation, municipal, and domestic purposes; and benefits from increased recreational activity resulting from project reservoirs.

In formulating plans for water development, to make hitherto unavailable water supplies available to meet present and ultimate water

requirements, intensive use was made of the planning studies conducted during the Klamath River Basin Investigation and studies for the California Water Plan. As previously indicated, not all of the estimated present impaired seasonal runoff of 108,700 acre-feet wasting from the basin could be conserved and put to beneficial use. The presently undeveloped water flows primarily in the lower reaches of the Shasta River and serves only a limited service area. Much of the undeveloped irrigable land in Shasta Valley lies in the northern and eastern portions, at elevations higher than lands presently irrigated. There are no significant sources of local water supply associated with these undeveloped lands. In planning, it was generally considered that lands within the presently irrigated area could be provided with increased water supply from local sources, while lands not presently irrigated would have to be provided with water from an imported source.

Possible methods of conserving a portion of the water presently flowing out of the valley in the Shasta River were studied with a view toward their practicability. These methods were:

1. Direct diversion from stream flow,
2. increased ground water development,
3. potential surface storage developments.

Factors involved in these studies, and generalized conclusions, are set forth in the following paragraphs.

Direct Diversion from Stream Flow

Because of the wide monthly and seasonal fluctuations of runoff within the Shasta River Basin, it was obvious that significant additional

development of water resources by direct diversion from streams is not practicable. This method of development, therefore, is not considered further in this chapter. The justification for this may be realized by considering present conditions which demand that some of the existing direct diversions from unregulated stream flow must be curtailed during the season of low runoff.

Increased Ground Water Development

The possibility of developing additional water supplies from more intensive use of ground water was considered, during the early stages of this investigation, as an alternative to potential surface reservoirs. At present most of the irrigation wells are located in the Gazelle-Grenada and Big Springs areas. Wells throughout the remaining portions of the valley are shallow, low-yielding, and only supply sufficient water for domestic and stock-watering purposes.

The major ground water producing geologic formation in Shasta Valley is the Pluto's Cave basalt. This formation covers about 50 square miles in the southeastern quarter of Shasta Valley, commencing at the base of Mount Shasta and extending northward somewhat beyond the Four Corners-Big Springs area. As is typical throughout the valley, yields of irrigation wells in this formation vary considerably, ranging from about 100 to 4,000 gallons per minute, and averaging about 1,300 gallons per minute. These wells vary from less than 100 feet to about 200 feet in depth.

If the water table in the Pluto's Cave basalt occurs at a reasonable depth throughout the higher elevations of this formation, water could be developed to irrigate lands having a favorable topographic position in relation to elevation of the water table. Development of a well

field in this formation might possibly provide water to these lands at a lesser cost than that developed from potential surface reservoirs, all of which lie at low elevations and from which water service would necessitate a considerable amount of pumping.

Formations capable of producing quantities of ground water sufficient for irrigation are limited. Due to the great differences in yield factors of existing wells, it would be necessary to drill a great number of test holes to determine satisfactory irrigation well locations. Geophysical techniques might be used advantageously, in conjunction with an exploration drilling program, to correlate drilled areas with undrilled areas. If a well field were developed in the Pluto's Cave Basalt area, it could have an effect on the yield of Big Springs and other nearby springs. The quantitative effect of such a development cannot be measured at this time. It is probable that the well field would have to be in actual operation for several years before its effect on the springs could be ascertained. After consideration of these factors, no further consideration was given to the possibility of developing additional ground water supplies as either an alternative or supplement to surface reservoirs being studied.

Potential Surface Storage Developments

As mentioned previously, a number of investigations have been made of the Shasta River Basin in conjunction with other studies, especially the Northeastern Counties and Klamath River Basin investigations. During these investigations twelve sites were considered as possible locations for constructing dams which would conserve local waters, or become

a part of an imported water system. These sites, shown on Plate 5, "Existing and Potential Facilities for Water Supply Development of Shasta Valley", are listed below.

Dam site	Location
Sites for local development	
Parks Creek	On Parks Creek, about 2 miles upstream from U. S. Highway 99.
Hole in the Ground	On Shasta River, about 3 miles below Dwinnell Reservoir.
Big Springs	On Shasta River, about 1/4 mile below confluence of Big Springs Creek with Shasta River.
Grenada Ranch	On Shasta River, about 3 miles southeast of the town of Grenada.
Upper and Lower Table Rock	On Little Shasta River, about 8 miles east of the town of Montague.
Upper and Lower Montague	On Shasta River, about 4 miles northwest of the town of Montague.
Copco Lake (enlarge existing dam)	On Klamath River, about 20 miles northeast of the town of Montague.
Jenny Creek	On Klamath River, about 18 miles northeast from the town of Montague.
Sites for importation development	
Iron Gate (Brush Creek)	On Klamath River, about 15 miles northeasterly from the town of Montague.
Red School	On Willow Creek, about 9 miles northeast of the town of Montague.
Hornbrook	On Klamath River, about 10 miles north of the town of Montague.
Box Canyon (Wagon Valley)	On Sacramento River, about 2 miles southwesterly from the town of Mount Shasta.

Of the sites considered for development of local water supplies, preliminary engineering and cost analyses showed that, in general, the cost of water would be high. These high costs would result from adverse topographic and geologic conditions, and from large storage capacities needed to conserve waters available, over and above amounts presently utilized under existing water rights. Because of this situation, Parks Creek, Hole in the Ground, Big Springs, and Table Rock reservoirs were eliminated from further consideration. The Montague and Grenada Ranch sites, that had been favorably reported on in Department of Water Resources Bulletin No. 83, were given more intensive study to determine their economic and engineering feasibility. Because of adverse geologic conditions the Montague Dam site was eliminated. A Gregory Mountain site, upstream from the Montague Dam site had been selected as a possible alternate, and this site was studied intensively. The Grenada Ranch and Gregory Mountain sites are reported on in detail in the following pages.

Either the Grenada Ranch or the Gregory Mountain Project would develop slightly more than 20,000 acre-feet of new water annually for irrigation and urban use. Considering the total ultimate supplemental requirement of 299,000 acre-feet per season, and that other opportunities for development of local supplies are limited, it may be seen that most of the ultimate supply will have to be imported from sources outside the basin.

During the formulation of the California Water Plan, a Hornbrook site, above the confluence of the Klamath and Shasta Rivers, was studied as a possible means of exporting surplus Klamath River water to the Sacramento River Basin, with local water service to Shasta Valley. However, further consideration of this site was eliminated in favor of alternative

downstream sites on the Klamath and Trinity Rivers, which could export the water at less cost. Importation of Klamath River water to Shasta Valley from an enlarged Copco Lake was also eliminated in favor of the Iron Gate site, due to higher costs encountered in raising the dam forming Copco Lake, and to the loss in power revenues from Copco No. 1 and Copco No. 2 Powerplants as a result of diverting the water above them. Of the various plans studied for importing water from the Klamath River to Shasta Valley, the plan to divert water from Iron Gate Reservoir and pump it through a conduit to Red School Reservoir on Willow Creek was found to be the least costly. However, the cost of water was found to be greatly in excess of present payment capacities for users in Shasta Valley.

The earlier investigations also included studies of plans to conserve waters of the Upper Sacramento River at the Box Canyon site for importation into the southern part of Shasta Valley. Diversion of a large quantity of water from the Upper Sacramento River to Shasta Valley would require either a pump lift with pipeline and canal, or a long tunnel. Preliminary studies of this diversion indicated that costs of water would be extremely high. A possibility exists for an allgravity diversion from the Upper Sacramento River to Shasta Valley; however, only a small amount of water could be gained.

In view of these possible means of developing local and imported water supplies, four important considerations were used as guides for further planning studies. These considerations were:

1. There seems to be no economically feasible method by which local surface runoff could be developed to meet present and

ultimate supplemental water requirements in the northeastern, eastern, and southern portions of Shasta Valley.

2. A large portion of the presently irrigated lands in Shasta Valley are located in the western part of the valley and emphasis was, therefore, placed on studies of the engineering feasibility and economic justification of the Grenada Ranch and Gregory Mountain projects on the Shasta River.

3. The best opportunity for importation of water, to augment local supplies, would be to divert water from the Klamath River at Iron Gate Reservoir for conveyance by pumping to the eastern side of Shasta Valley.

4. In view of the present (1961) construction of an Iron Gate Reservoir by the California-Oregon Power Company, only limited investigation was made of the engineering feasibility of the Shasta Valley Import Project.

The Grenada Ranch, Gregory Mountain, and Montague projects are discussed in detail in the following pages.

Grenada Ranch Project

The Grenada Ranch Project would consist of a reservoir with a storage capacity of 22,400 acre-feet, at the Grenada Ranch site on the Shasta River, about two miles southeast of the City of Grenada, a pumping and conveyance system for distributing the conserved waters, and basic recreational facilities. It would provide water for irrigation use in the project service area, south and west of Grenada, provide water for municipal and industrial use in the Yreka area, and provide the basis for enhancement of the recreational potential of Shasta Valley.

Grenada Ranch Dam and Reservoir site looking northwest.

The project would provide a firm regulated supply of new water of about 22,200 acre-feet seasonally. Of this amount, 17,500 acre-feet would be available for irrigation use and 4,700 acre-feet would be available for municipal and industrial purposes. The location of the project is shown, and its principal features are delineated on Plate 6, "Grenada Ranch Project".

The three primary sources of water supply to a reservoir at Grenada Ranch would be (1) seepage and spill from Dwinnell Reservoir, (2) excess runoff from Parks Creek, and (3) winter flow from numerous springs, the largest of which are located in the vicinity of Big Springs Creek. Water from a reservoir at Grenada Ranch may be expected to have a hardness of about 170 parts per million, which is moderately hard, but would be suitable for agriculture, domestic, and municipal uses, and other beneficial purposes.

Topographic maps of the dam site, at a scale of one inch equals 400 feet, with a contour interval of five feet, and of the reservoir site at the same scale, with a contour interval of ten feet, were prepared during the investigation. Water surface areas and storage capacities of Grenada Ranch Reservoir at various stages of water surface elevation, as determined from these maps, are presented in Table 26.

TABLE 26

AREAS AND CAPACITIES OF GRENADA RANCH RESERVOIR

Water surface elevation, USGS datum, in feet	Depth of water at dam, in feet	Water surface area, in acres	Storage capacity, in acre-feet
2,530	0	0	0
2,540	10	125	630
2,550	20	330	2,900
2,560	30	534	7,200
2,570	40	690	13,300
2,580	50	1,124	22,400

Geology

Based on preliminary geologic investigations, the Grenada Ranch Dam site is considered suitable for an earthfill or rockfill dam of the height considered herein.

The abutments of the Grenada Ranch Dam site are underlain by a series of andesitic lava flows which are each from 50 to 100 feet in thickness. These flows are characterized by prominent blocky jointing, vesicular contacts between flows, and a general northeasterly dip of 40 to 55 degrees. Near the surface, the blocky joints in the bedrock of both abutments are partially filled with clay; but the joints are open from a depth below ground surface of about 10 feet to over 130 feet. Large amounts of grout would be required to prevent serious leakage through the dam site. Leakage through the pervious volcanics which bound the reservoir area probably would not be excessive because overlying soils would act as an

impervious blanket and the ground water table slopes toward the river channel. A few minor shear zones were noted in the bedrock, but these probably would not require special treatment. Bedrock is exposed at the base of the left abutment and across the middle of the right abutment. Elsewhere on the abutments, the bedrock is covered by residual and colluvial silty clay, and by loose rock to a depth of eight feet on the left, and two feet on the right abutment. The average slopes of the left and right abutments are 42 and 54 percent, respectively.

Deep subsurface drilling indicated that from the base of each abutment, the bedrock surface steepens sharply to form the nearly vertical walls of a buried gorge beneath the channel. Alluvial sediments have filled this hidden gorge to a measured depth of over 130 feet. The top 30 feet of the sediments are pervious gravel, sandy silt, and silty sandy gravel. Impervious to semipervious clayey gravel, with small lenses of impervious clay and of pervious sandy gravel, comprise the lower zone.

Thorough grouting of both abutments would be required to control leakage around the dam. Approximately eight feet of residual soil and loose rock would have to be stripped from the left abutment and about two feet from the right abutment under the impervious core of the dam. A cutoff in the channel would be excavated to a depth of about 50 feet, through the pervious sandy gravel and into the clayey gravel, and backfilled with impervious material. About eight feet of organic silts would be removed from the channel section under the rockfill, and about two feet of residual soil would be stripped from the abutments.

The spillway could be excavated across the left abutment in jointed and fractured andesitic lava. Spoil from the spillway excavation would be salvaged for use in the rockfill section of the dam.

Grenada Ranch Dam site looking downstream.

Four small auxiliary dams would be required on the rim of Grenada Ranch Reservoir. One auxiliary dam would be located about 1,000 feet east of the right abutment of the main dam, and the remaining three would be located 1,000 feet, 2,000 feet, and 2,200 feet, respectively, westerly from the left abutment. The height of the auxiliary dams would range from a minimum of 3 feet to a maximum of 25 feet. The crest lengths of the dams would vary from a minimum of 400 feet to a maximum of 3,600 feet.

Stripping for the four auxiliary dams would be limited to removal of a root zone, from one to three feet deep, at the sites. The colluvial and alluvial deposits at the auxiliary dam sites would act as an impervious blanket overlying the pervious volcanics.

Sufficient quantities of suitable riprap, rockfill, and impervious construction materials are available within 6,000 feet of the dam site. The nearest source of aggregate for concrete is located about 11 miles northwest of the dam site.

Design

Engineering, economic, and geologic factors, together with the maximum storage capacity that could be created without flooding the springs in the Big Springs area, were considered in selecting the size of Grenada Ranch Reservoir. It is believed that flooding of the springs might change their rate and/or place of discharge. It was found that this latter limitation on the size of the reservoir was the controlling factor in the reservoir sizing studies. As stated previously, the reservoir would have a storage capacity of 22,400 acre-feet.

The estimated average seasonal present impaired runoff from the 240 square miles of drainage basin above the Grenada Ranch Dam site, for the 35-year base period from 1920-21 through 1954-55, is about 82,000 acre-feet. During the base period, the seasonal runoff ranged from a maximum of about 111,000 acre-feet (during the season of 1941-42) to a minimum of about 56,000 acre-feet (during the season 1933-34).

The Grenada Ranch Dam site is located about 7 miles downstream from Dwinnell Reservoir. The principal sources of water supplies to be developed are unused winter flows of Big Springs and Parks Creek, both of which enter the Shasta River about 4 miles downstream from Dwinnell Reservoir. It is estimated that the presently unused winter discharge of the Big Springs area varies from 30,000 acre-feet to 35,000 acre-feet between October 1 and March 15. In addition, unused winter flows from Parks Creek average about 4,000 acre-feet per season.

A substantial portion of the water supply of the Shasta River available at the Grenada Ranch site is subject to use downstream under claim of riparian and appropriative rights. In addition to these rights, the Shasta River supports considerable numbers of anadromous and native fish which require a substantial quantity of stream flow for their continued subsistence. Therefore, only flows not presently used could be stored during the winter season for release during the following irrigation season. A detailed discussion of stream flow maintenance requirements for fish is presented in Appendix B, "Preliminary Report on Fish and Wildlife in Relation to Plans for Water Development in Shasta Valley".

Estimates of the amount of new firm seasonal yield from the Grenada Ranch Reservoir were determined from monthly operation studies.

In conducting these studies consideration was given to prior rights and to fishery maintenance requirements. Prior rights not satisfied by water entering the stream from the drainage area below the reservoir, would be satisfied by reservoir releases. The maximum releases for these purposes would be limited to the amount of inflow to the reservoir. Fishery maintenance flows not satisfied by the downstream supply also would be fulfilled by reservoir releases in sufficient quantity to meet requirements, except during dry years when flows would be somewhat reduced in accordance with the dry-year clause discussed in Appendix B.

A minimum dead storage allowance of 1,600 acre-feet was used in the operation studies for Grenada Ranch Reservoir. This amount was assumed to be sufficient to allow for sedimentation in the reservoir during the economic life of the project, and to allow minimum storage for recreational purposes. The studies show that during the 35-year base period, the reservoir would be drawn down to dead storage during the recreational season less than 2 percent of the time.

New seasonal yield from the reservoir was assumed to meet the required irrigation and municipal demands of the project service area. The monthly quantities of seasonal demand used in the operation studies are presented in Table 27. The monthly schedules of required fishery maintenance flows, and the maximum, average, and minimum flows available for fish under historic and project conditions, are presented in Table 28. A seasonal summary of the operation study, including estimates of resultant flow available for fishery maintenance, is presented in Table 29.

TABLE 27

MONTHLY QUANTITIES OF SEASONAL DEMAND FROM GRENADA RANCH RESERVOIR

(In acre-feet)

Month	Demand schedule: Municipal and industrial	Demand schedule: Irrigation	Demand schedule: Total	Month	Demand schedule: Municipal and industrial	Demand schedule: Irrigation	Demand schedule: Total
October	600	0	600	April	300	1,700	2,000
November	300	0	300	May	300	2,900	3,200
December	200	0	200	June	400	2,900	3,300
January	200	0	200	July	700	3,500	4,200
February	200	0	200	August	700	3,300	4,000
March	200	0	200	September	600	2,200	2,800
				SEASONAL TOTALS	4,700	16,500	21,200

TABLE 28

MONTHLY SCHEDULES OF REQUIRED FISHERY MAINTENANCE FLOWS AND MAXIMUM, AVERAGE, AND MINIMUM MONTHLY FLOWS AVAILABLE FOR FISH UNDER HISTORIC AND PROJECT CONDITIONS FOR SHASTA RIVER

(In acre-feet)

Month	Required fishery maintenance flows[a]		Recorded historical flows available for fish[b]			Estimated flows available for fish with Grenada Ranch Reservoir in operation[c]		
	Schedule Number 1	Schedule Number 2	Maximum	Average	Minimum	Maximum	Average	Minimum
October	9,200	6,100	11,800	8,800	6,200	11,100	8,100	4,800
November	11,900	5,200	14,000	10,200	7,000	19,100	10,200	3,900
December	9,200	4,600	26,700	14,400	7,400	29,200	10,700	3,500
January	9,200	4,600	43,800	16,400	6,800	35,700	10,000	3,200
February	8,300	4,200	37,600	17,900	7,400	27,700	10,000	2,900
March	3,100	3,100	38,200	16,600	6,100	36,300	9,200	2,000
April	3,000	3,000	42,300	11,900	2,200	26,800	6,800	1,000
May	3,100	3,100	22,400	7,200	1,800	23,900	5,000	1,500
June	1,800	1,800	16,900	5,600	1,100	17,500	3,500	1,700
July	1,800	1,800	7,100	2,300	800	16,400	3,500	1,800
August	1,800	1,800	5,900	2,300	500	5,000	3,500	1,500
September	3,900	3,900	6,200	4,400	2,400	6,400	3,800	1,800
TOTALS	66,300	43,200		118,000			82,600	

a/ A detailed discussion of the required flows for two alternative fishery maintenance plans is presented in Appendix B, "Preliminary Report on Fish and Wildlife in Relation to Plans for Water Development in Shasta Valley".

b/ Shasta River below Yreka Creek for 19-year period of record from October 1933 through December 1941 and from January 1945 through September 1955. The average historic seasonal runoff for the 19-year period of record is about 8 percent greater than the estimated average presently impaired seasonal runoff for the 35-year base period.

c/ Shasta River above Yreka Creek for 35-year base period from 1920-21 through 1954-55 under present impaired conditions.

TABLE 29

SEASONAL SUMMARY OF GRENADA RANCH RESERVOIR OPERATION

(In acre-feet)

Season	Present impaired inflow	Releases to satisfy prior rights	Fishery maintenance release	Net evaporation	Reservoir yield[1/] Municipal and industrial	Reservoir yield[1/] Irrigation	Spill	(Sept. 30) Storage at end of season	Resultant flow for fishery maintenance, Shasta River above confluence with Yreka Creek
1920-21	101,400	18,800	26,200	2,300	4,700	16,500	22,200	17,900	133,600
22	85,400	22,600	38,900	1,700	4,700	16,500	10,000	8,900	90,000
23	78,800	23,200	33,700	1,700	4,700	16,500	3,400	4,500	81,000
24	71,300	21,800	28,600	1,700	4,700	16,500	0	2,500	52,200
25	79,900	23,600	21,400	2,100	4,700	16,500	3,400	10,700	58,400
1925-26	79,500	23,200	38,300	1,700	4,700	16,500	200	5,600	71,900
27	94,900	26,900	22,100	2,100	4,700	16,500	14,400	13,800	115,100
28	97,900	28,400	35,900	1,500	4,700	16,500	16,600	8,100	100,900
29	81,400	23,700	38,400	1,800	4,700	16,500	300	4,100	60,400
30	61,100	18,700	20,600	1,500	4,700	16,500	0	3,200	58,600
1930-31	56,100	19,600	17,000	1,100	4,700	15,200	0	1,700	41,700
32	57,500	18,800	17,200	1,400	4,700	15,300	0	1,600	40,400
33	57,500	17,200	17,800	1,400	4,700	16,400	0	1,600	40,000
34	56,100	19,000	17,400	1,500	4,700	10,700	0	4,400	35,400
35	56,300	17,300	18,800	1,400	4,700	16,500	0	2,000	41,600

TABLE 29 (continued)

SEASONAL SUMMARY OF GRENADA RANCH RESERVOIR OPERATION

(In acre-feet)

Season	Present impaired inflow	Releases to satisfy prior rights	Fishery maintenance release	Net evaporation	Reservoir yield[1/]		Spill	(Sept. 30) Storage at end of season	Resultant flow for fishery maintenance, Shasta River above confluence with Yreka Creek
					Municipal and industrial	Irrigation			
1935-36	61,900	17,400	19,200	1,700	4,700	16,500	400	4,000	47,000
37	59,300	18,700	18,300	1,500	4,700	16,500	0	4,000	44,900
38	87,800	18,500	14,800	2,300	4,700	16,500	16,100	18,500	148,900
39	70,200	20,600	40,100	1,400	4,700	16,500	1,700	3,700	77,800
40	76,100	22,200	17,700	1,800	4,700	16,500	5,300	11,600	94,700
1940-41	134,200	18,500	31,300	2,300	4,700	16,500	51,300	21,000	152,000
42	110,900	18,700	33,500	2,100	4,700	16,500	36,800	19,600	174,300
43	102,200	18,500	50,300	2,200	4,700	16,500	11,700	17,900	87,800
44	81,900	19,200	47,500	1,700	4,700	16,500	400	9,800	67,800
45	76,800	20,600	33,500	1,900	4,700	16,500	0	9,400	66,000
1945-46	81,300	24,500	34,900	1,700	4,700	16,500	3,200	5,200	82,900
47	73,800	23,900	27,300	1,700	4,700	16,500	300	4,600	49,500
48	81,200	20,300	25,700	2,200	4,700	16,500	2,300	14,100	59,400
49	83,300	25,200	40,200	1,700	4,700	16,500	1,300	7,800	77,400
50	77,900	19,700	31,500	1,900	4,700	16,500	1,800	9,600	66,300
1950-51	88,400	24,800	27,600	1,700	4,700	16,500	12,200	10,500	109,300
52	107,600	20,000	29,800	2,200	4,700	16,500	26,400	18,500	123,600
53	110,200	22,300	26,500	2,100	4,700	16,500	40,500	16,100	145,400
54	106,800	24,900	30,600	1,800	4,700	16,500	30,400	14,000	121,000
55	83,900	21,900	46,000	1,600	4,700	16,500	0	7,200	72,100
35-year base period average	82,000	21,200	29,100	1,800	4,700	16,300	8,900	9,100	82,600

1/ Project yield comprises 21,200 acre-feet per season released from reservoir and 1,000 acre-feet of present water supply salvaged through reduced canal losses.

It was estimated that incorporation of the Grenada Irrigation District diversion facilities into the Grenada Ranch Project distribution system would result in a saving of about 1,000 acre-feet per season of the water presently diverted by the irrigation district. The district presently pumps from the Shasta River and conveys the water about five miles in an unlined canal to the service area. Large losses occur in reaches of the canal passing through fractured volcanic formations. It was assumed that the water presently lost from the canal percolates to ground water and returns to the river. Under the proposed project nearly all of this five mile reach of canal would be concrete lined. The salvage of 1,000 acre-feet per season of presently diverted water, in addition to the firm seasonal reservoir releases of 21,200 acre-feet, would result in a total seasonal project yield of about 22,200 acre-feet.

A comparison of the costs of several types of structures showed a rockfill dam with an earth core to be the least expensive. Design and cost of a rockfill dam with a height of 64 feet above stream bed, and a crest elevation of 2,593 feet, U. S. Geological Survey datum, was selected to illustrate the cost of a Grenada Ranch Dam. The dam would have a crest length of 475 feet, a crest width of 25 feet, and side slopes of 3 to 1. The compacted earth impervious section would have a crest width of 30 feet and side slopes of 0.5 to 1. Two well-graded, transition zones, each 20 feet in width, between the impervious core and the rockfill zones, would act as filters to prevent piping and washing of fines from the core into the voids of the rockfill zone. A berm 50 feet in width would be located on the upstream toe at an elevation of 2,560 feet. The volume of fill would be about 213,000 cubic yards.

The standard project flood at the Grenada Ranch site was estimated to have a peak inflow of 16,600 second-feet, after its reduction by temporary storage in the upstream Dwinnell Reservoir. After routing the standard project flood through Grenada Ranch Reservoir, it was estimated that the peak spillway discharge would be 14,700 second-feet. A lined chute spillway, excavated around the left end of the main dam, would convey the spillway discharge to the Shasta River channel below the dam. The spillway crest would have a length of 170 feet, and would be an ungated overpour-type with a converging concrete lined chute and an ogee weir control section. The maximum spillway surcharge during the standard project flood would be 8 feet. An additional 5 feet of freeboard to the crest of the dam would be provided. The spillway would also be sufficient to safely pass the maximum probable flood, having an estimated peak discharge of 20,800 second-feet, with a surcharge of 11.5 feet and remaining freeboard of 2.5 feet.

The outlet works at the dam would consist of a 48-inch diameter reinforced concrete pipe placed in a trench beneath the dam on the right abutment. Emergency shutoff of the outlet pipe would be provided by operation of two-gate valves contained in a submerged intake structure located just upstream from the dam. Normal releases from the reservoir for prior rights and fishery maintenance would be controlled by a 48-inch hydraulically operated butterfly valve, which would discharge into a concrete weir box located just below the dam. From the weir box the releases could enter an existing irrigation ditch or the Shasta River.

The land within the Grenada Ranch Reservoir area is utilized for cattle grazing. The area comprises about 1,650 acres at the dam crest elevation. Improvements within the area consist of two farms. About

2.6 miles of private unimproved dirt road and 0.8 mile of power distribution lines would require relocation. In addition, a section of county road, including a bridge across the upper end of the proposed reservoir, would be replaced with an earthfill embankment and culvert-type crossing.

The existing conveyance and distribution system of the Grenada Irrigation District would be enlarged, improved, and utilized as part of the Grenada Ranch Project. The system would convey the present water supply of the district as well as the new supply for municipal and irrigation purposes. The system would consist of about 42 miles of canals, and seven pumping plants. The main canal of the Grenada Irrigation District is unlined and has a high seepage loss in reaches of porous volcanic materials. It was estimated that at present up to 25 percent of the water pumped from the river is lost from the main canal before it reaches the low-level canal and the second pumping station of the system. For this reason, over 80 percent of the initial reach of main canal would be lined. The remaining portion of the canal, located in impervious alluvial deposits, would not require lining.

The branch canal and laterals would be primarily in impervious material and would not require lining. For cost estimating purposes, it was assumed that the canal lining would have a thickness of 3 inches of concrete. The distribution system is shown on Plate 5.

The Grenada Irrigation District's pumping plant, for lifting water from the Shasta River, is located about 1 mile upstream from the Grenada Ranch Dam site. This plant would be inundated by the reservoir. Pumping plant No. 1, which would replace the existing plant, would contain

two 20,000 gallons per minute units, and one 4,000 gallons per minute unit. The static pump lift would vary from a minimum of about 25 feet to a maximum of about 59 feet, depending upon reservoir stage, and would average about 30 feet.

From Pumping Plant No. 1, the main canal, with a capacity of 125 second-feet, would extend westward for a distance of about 5.5 miles along the alignment of the existing canal of the district, to Pumping Plant No. 2. Water for irrigation purposes would be served enroute directly from the canal to a portion of the project service area. At Pumping Plant No. 2, water would be diverted northward by gravity through 3 miles of existing canal, having a capacity of about 10 second-feet, to serve a portion of the existing Grenada Irrigation District service area.

Pumping Plant No. 2 would have a capacity of 93 second-feet and would lift water into both the north and south branch canals. It would replace the second existing pumping station of the Grenada Irrigation District. The south branch canal would have a capacity of 52 second-feet at its intake and 8 second-feet at its terminal, and would extend southward for a distance of about 7.5 miles.

The north branch canal would extend northward for a distance of about 9.7 miles, and would have an initial capacity of 46 second-feet and a terminal capacity of 15 second-feet. In addition to conveying water for irrigation use in the project service area, the north branch canal would convey water in a westerly direction for a distance of about 7.6 miles to the existing Greenhorn Reservoir on Greenhorn Creek, for municipal and industrial use in the Yreka area. The Yreka extension canal would have a capacity of about 12 second-feet.

Recreation was considered an important element of the Grenada Ranch Project and, therefore, public recreation facilities were considered to be an integral part of the project. Public camp units, picnic units, and boat launching ramps would be located in the most accessible and attractive areas around the reservoir. These facilities would be provided in stages during the life of the project, with experienced recreational use the basis for staging the required development. It was estimated that the initial development of each camp and picnic site would cost about $1,500 and $750, respectively. Public boat launching facilities would consist of ramps constructed of reinforced concrete, about 30 feet in width and about 200 feet in length. The initial cost of each boat ramp was estimated to be about $45,000. Since it was assumed that land acquired for the reservoir would extend well beyond the maximum pool elevation to avoid heavy severance damages, no additional lands would be required for the planned recreation facilities.

The Grenada Ranch Project would have an adverse effect on a portion of the Shasta River fishery resource, because of reduction of stream flow below the dam and because of a loss of spawning area above the dam, if facilities were not provided in the project to compensate for such loss. To compensate for this loss, consideration was given to various fishery maintenance plans, all of which would require substantial stream maintenance flows together with artificial propagation facilities. Stream flow maintenance plans and cost estimates of artificial propagation facilities were prepared by the Department of Fish and Game for four conditions, and are discussed in detail in Appendix B. Two of these conditions are for new

independent facilities on the Shasta River and two are for facilities combined with the existing Mount Shasta Fish Hatchery. Under each plan, the size and cost of the facilities would depend on the stream flow maintenance schedule adopted.

The flows available for fish, under the plan of operation utilized herein, would meet the flows required under schedule number 1 described in Appendix B. The average seasonal flows available for fish under this operation would exceed the seasonal flow requested in schedule number 1 by about 25 percent.

Under the plan utilized herein, trapping and spawning facilities would be built at the base of the dam, where the adult fish would be held in suitable ponds or tanks during spawning. The eggs would then be transported and hatched at the new facilities combined with the Mount Shasta Fish Hatchery. After rearing was completed, the fingerlings would be transported and planted at the base of the dam. The facilities for this plan would have an estimated capital cost of about $250,000, and an estimated average annual operation and maintenance cost of about $23,000.

Pertinent data with respect to general features of the Grenada Ranch Project, as designed for cost estimating purposes, are presented in Table 30.

TABLE 30

GENERAL FEATURES OF GRENADA RANCH PROJECT

Characteristics of Dam Site	
Drainage area, in square miles	240
Estimated average seasonal present impaired runoff, in acre-feet	82,000
Estimated average seasonal net depth of evaporation, in feet	1.97
Elevation of stream bed, USGS datum, in feet	2,529
Main Dam	
Type	Rockfill with impervious core
Crest elevation, USGS datum, in feet	2,593
Crest length, in feet	475
Crest width, in feet	25
Side slopes, upstream and downstream	3:1
Volume of fill, in cubic yards	213,000
Height of spillway lip above stream bed, in feet	51
Spillway lip elevation, USGS datum, in feet	2,580
Freeboard above spillway lip, in feet	13
Auxiliary Dams	
Number required	4
Types	Homogeneous and rockfill with impervious core
Crest elevation, USGS datum, in feet	2,593
Total crest length, in feet	4,675
Maximum height above natural ground, in feet	18
Volume of fill, in cubic yards	105,000
Reservoir	
Surface area at spillway lip, in acres	1,120
Gross storage capacity at spillway lip, in acre-feet	22,400
Dead storage capacity, in acre-feet	1,600
Active storage capacity, in acre-feet	20,800
Type of spillway	Ungated ogee weir with converging concrete lined chute
Net crest length of spillway, in feet	170
Spillway discharge capacity, with 4.7-foot residual freeboard, in second-feet	14,700
Type of outlet	
Through dam	48-inch diameter, reinforced concrete conduit
From reservoir	Pumping plant
Net firm seasonal yield, in acre-feet	
Irrigation	
From reservoir	16,500
From salvage of main canal seepage losses	1,000
Municipal and industrial (from reservoir)	4,700
TOTAL	22,200

TABLE 30 (continued)

GENERAL FEATURES OF GRENADA RANCH PROJECT

Conveyance and main distribution facilities					
	Pumps				
Facility	Capacity, in second-feet	Lift, in feet	Capacity, in second-feet	Length, in miles	Loss of elevation, in feet
Pumping Plant No. 1	112-250[a]	59-25[a]			
Main Canal			125	5.5	8.3
Pumping Plant No. 2	93	56			
South Branch Conduit					
Section 1			52	1.3	1.7
Lateral A-S			12-7	2.5	13.2
Section II					
Pumping Plant No. 1-S	40	80			
Canal			39	1.3	1.9
Lateral B-S			16-8	3.7	9.8
Section III					
Pumping Plant No. 2-S	23	82			
Canal			21-8	4.9	11.5
North Branch Conduit					
Section I			46	3.8	13.0
Lateral A-N			4	1.0	5.0
Section II					
Pumping Plant No. 1-N	25	72			
Canal			25	0.8	1.9
Lateral B-N			6	2.8	9.8
Section III					
Pumping Plant No. 2-N	19	108			
Canal			19-15	5.1	15.4
Lateral C-N			3	1.3	6.6
Yreka Extension					
Pumping Plant No. 3-N	12	73			
Canal			12	7.6	134.0[b]
TOTAL LENGTH OF CANALS				41.6	

a. Variable depending on reservoir stage.
b. Large loss in elevation due to elevation of spillway of Greenhorn Reservoir which was the assumed delivery point for the municipal and industrial supply.

Project Costs

The initial capital cost of the Grenada Ranch Project was estimated to be about $3,756,000. Of this cost, $2,038,000 would be for the dam and reservoir, $1,359,000 would be for the conveyance and main distribution facilities, $109,000 would be for recreation facilities, and $250,000 would be for fishery maintenance facilities. Corresponding average annual and present-worth costs, using an interest rate of 4 percent per annum and a repayment period of 50 years and including costs of future stages of recreation facilities, were estimated to be about $310,800 and $6,676,000, respectively. The estimated unit cost of the 22,200 acre-feet per season of new project yield would be about $14 per acre-foot. A summary of initial capital costs, annual costs, and capital costs that include the present worth of total annual expenditure for operation, maintenance, replacement and electrical energy are presented in Table 31. Detailed cost estimates of the dam and reservoir, and of the conveyance and main distribution system are presented in Appendix E, "Estimates of Cost". A summary of the estimated number required and cost of the public recreation facilities at Grenada Ranch Reservoir, by decades, is presented in Table 32. A detailed discussion of the recreational aspects of the project are on file at the Department of Water Resources.

TABLE 31

SUMMARY OF ESTIMATED CAPITAL, PRESENT-WORTH, AND AVERAGE ANNUAL COSTS OF GRENADA RANCH PROJECT

Facility	Initial capital costs to construct works	Present worth of capital costs, including operation, maintenance, replacement and electrical energy	Average annual equivalent costs a/
Dam and reservoir	$2,038,000	$2,305,000	$107,300
Conveyance and main distribution facilities	1,359,000	2,256,000	105,000
Electrical energy for pumping	---	1,207,000	56,200
Recreation facilities	109,000	165,000	7,700
Fish life maintenance facilities and operation	250,000	743,000	34,600
TOTALS	$3,756,000	$6,676,000	$310,800

a/ Present worth and average annual equivalent values are based on a 50-year period and an interest rate of 4 percent per annum.

TABLE 32

ESTIMATED RECREATIONAL USE, AND NUMBER AND COST OF
PUBLIC RECREATION FACILITIES AT GRENADA RANCH RESERVOIR

Year	Estimated recreational use, in visitor-days per season	Public recreation facilities: Developed camp sites to be installed	Developed picnic sites to be installed	Boat ramps to be installed	Estimated cost of facilities: Camp	Picnic	Boat ramp	Total
1970	6,000	30	25	1	$ 45,000	$19,000	$45,000	$109,000
1980	26,000	10	10	--	15,000	8,000	---	23,000
1990	37,000	12	8	--	18,000	6,000	---	24,000
2000	47,000	15	8	1	22,000	6,000	45,000	73,000
2010	58,000	18	7	--	27,000	5,000	---	32,000
2020	68,000	--	--	--	---	---	---	---
TOTALS		85	58	2	$127,000	$44,000	$90,000	$261,000

Service Area

The service area of Grenada Ranch Project was selected on the basis of its location with respect to the Grenada Ranch Reservoir, and because it contains the largest single block of contiguous, good quality, irrigable land, presently without a firm water supply that could readily be served from the reservoir. The soils of the service area are relatively light textured, and well suited for intensive farming practices such as the growing of potatoes and other truck and field crops. In the higher reaches the soils contain sands and gravels that may best be irrigated by sprinklers. On the whole, these lands would yield higher net returns than the average of the remaining unirrigated lands in Shasta Valley. The service area would comprise a total of about 15,780 acres, including the entire Grenada Irrigation District of about 1,840 acres. The location of the service area is shown on Plate 5.

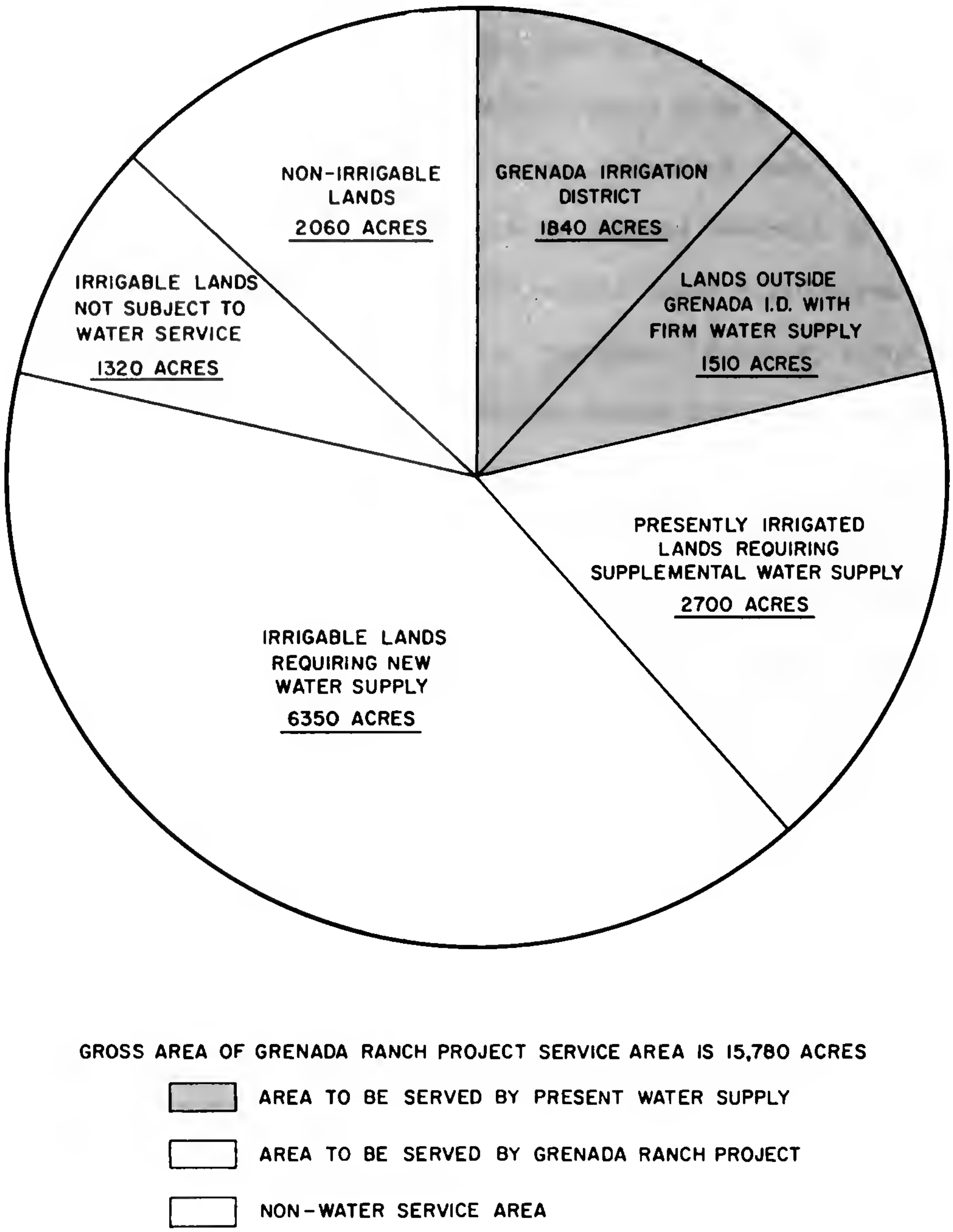
Present Service Area. In recent reports of the Grenada Irrigation District to the California Districts Securities Commission, it is indicated that over 90 percent of the irrigable land in the district is presently under irrigation. Reports of the Watermaster Service of the Department of Water Resources, indicate that the Grenada Irrigation Districts' presently available water supply, pumped from the Shasta River, should be adequate to fully serve all the lands of the district. The district would benefit, however, from the Grenada Ranch Project in that there would be a reduction from present operating costs. This reduction would result from savings in annual pumpage and conveyance costs due to lower initial pump lift, higher pumping plant efficiencies, reduced seepage

losses of water pumped, lower operation and maintenance costs, and a somewhat lower unit cost of electric energy.

In 1953, about 4,210 acres of the land within the proposed service area, exclusive of those now receiving water from the Grenada Irrigation District, were under irrigation. It was estimated that to obtain optimum yields these 4,210 acres would have an average seasonal water requirement of about 13,800 acre-feet. At present these 4,210 acres receive a total of 8,100 acre-feet of water per year. However, since there is an overabundance of water during the spring months but a deficiency in the late summer and fall, the entire quantity was considered to be the equivalent, in growing efficienty, of 5,000 acre-feet of water applied at the proper times. This 5,000 acre-feet would provide a full water supply for 1,510 acres. Thus, in order to provide a full water supply to the total 4,210 acres, a supplemental supply sufficient to irrigate 2,700 acres (5,700 acre-feet per season) would be needed. This need for supplemental water, and its present and future use, is shown graphically through land use data, in Figure 2.

<u>Project Service Area</u>. Under the project, in addition to lands presently with a firm water supply, the irrigated area would increase from a projected 2,700 acres in 1970 to 9,050 acres in 1990, and remain at that figure thereafter. The changing acreages and crop patterns, for each decade from 1970 to 2020, are shown in Table 33.

FIGURE 2



PRESENT AND PROJECTED FUTURE LAND USE WITHIN THE GRENADA RANCH PROJECT SERVICE AREA

DEPARTMENT OF WATER RESOURCES 1961

TABLE 33

PROJECTED CROP PATTERN ON LANDS SERVED BY THE GRENADA RANCH PROJECT

(In acres)

Crop	Year					
	1970	1980	1990	2000	2010	2020
Truck crops	---	300	530	850	1,280	1,700
Field crops	---	300	530	850	1,280	1,700
Alfalfa seed	60	2,000	4,150	4,350	3,790	3,200
Alfalfa hay	730	1,900	2,990	2,620	2,340	2,130
Pasture	1,710	2,000	530	---	---	---
Grain	200	500	320	380	360	320
TOTALS	2,700	7,000	9,050	9,050	9,050	9,050

In addition to the proposed agricultural service area, the Grenada Ranch Project would provide water for municipal and industrial needs. The principal area served would be Yreka. The present municipal water supply of Yreka is derived from wells and from the newly constructed Greenhorn Reservoir on Greenhorn Creek. These sources can provide an estimated safe seasonal supply of about 1,800 acre-feet. On the basis of a requirement of 250 gallons per day per capita, this supply would be adequate to meet the needs of a population of about 6,400, which it was estimated will be reached by about 1970. By the year 2020, it was estimated that the city will reach a population of about 20,000, and will require an estimated supplemental seasonal water supply of about 3,800 acre-feet.

In addition to Yreka, other communities within Shasta Valley, including Montague, Grenada, and Gazelle, are expected to experience an increase in population of more than 3,000 by the year 2020. The seasonal

supplemental water requirements for this increased population was estimated to be about 900 acre-feet in 2020. This estimate was made on the basis of the same per capita requirement as was used in determining the requirements of Yreka. A summary of the projected municipal, industrial, and irrigation seasonal water requirements, by decade, to be supplied by the Grenada Ranch Project, is presented in Table 34.

TABLE 34

SUMMARY OF PROJECTED SEASONAL WATER REQUIREMENTS
TO BE MET FROM THE GRENADA RANCH PROJECT

(In acre-feet)

Year	Seasonal water requirement				
	Municipal and industrial				
	Yreka	Other urban communities	Subtotal	Irrigation	Total
1970	0	30	30	9,100	9,130
1980	540	50	590	19,400	19,990
1990	1,180	90	1,270	22,500	23,770
2000	2,080	210	2,290	20,100	22,390
2010	3,190	440	3,630	18,600	22,230
2020	3,800	900	4,700	17,300	22,000

It should be noted that the proposed service area was selected for the purpose of determining the engineering feasibility and economic justification of the Grenada Ranch Project. Further study of the project and desires of local interests might result in changes in the area to be served by the project.

Project Benefits

The primary benefits that would accrue to the Grenada Ranch Project would be derived from increased irrigation, municipal, and industrial water supplies and from increased water-associated recreational activity made possible by the project.

Direct irrigation benefits refer to those benefits derived through the value added by the project to the net assets of those farms receiving water from the project. In general, benefits were estimated by subtracting from the gross farm income all farm costs except interest on the value of the land and the cost of water. The remaining amount was termed the return to land and water. The dollar values of returns to land and water was determined for all dry-farmed and irrigated crops grown in the project service area. Next the crop pattern for the project service area and corresponding returns to land and water were determined as they would be for the entire repayment period without the project and with the project. The net benefit was the difference between returns to land and water with the project and those that would accrue to the same area if no project were built.

Total net benefits were expressed as the present worth, at an interest rate of four percent per annum, of all annual benefits that would accrue throughout the 50-year repayment period (1970-2020 in this case). Annual benefits were expressed as the annual equivalent of the present worth computed at an interest rate of four percent per annum. This placed net benefits on the same basis as capital and annual costs of the project for the purposes of determining economic justification.

The benefits from irrigation projects are primarily dependent upon the net gain to land due to the project and the project crop pattern. The validity of the benefit estimates depend, to a large extent, upon assumptions that must be made regarding future conditions. Critical assumptions used for this analysis were:

1. That future price-cost relationships would approximate those which prevailed during the five year period from 1952 through 1956, especially with respect to agricultural production and income.

2. That yields would remain comparable to, or greater than, those for the period from 1952 through 1956.

3. That the State and the service area populations would continue to increase.

4. That the proposed service area would maintain its share of the total state agricultural production.

Based upon prices, costs and yields for the 1952-1956 period, per acre returns to land and water, for representative crops in the service area, would be $13.25 for barley, $15.25 for irrigated pasture, $24.85 for alfalfa hay and $52.30 for potatoes. Returns for other truck and field crops are greater than those for alfalfa but less than those for potatoes. Based on the projected crop distribution for each decade, as shown in Table 32, the average return to land and water per acre for the service area would be $26.80 for the 1970 to 1980 decade, and $32.05 for the 2010 to 2020 decade. Subtracting the returns creditable to dry-farming from these values, the per acre benefits would be $23.05 and $28.30 for the 1970-1980 and 2010-2020 decades, respectively. The total net irrigation

benefits for the 50-year period of analysis, on a present worth basis, was estimated to be about $4,060,000 for the Grenada Ranch Service Area. The average annual equivalent would be about $189,000.

An additional increment of irrigation benefit would accrue to the Grenada Ranch Project in the form of reduced operating costs of the Grenada Irrigation District. It was estimated that there would be a saving of $6,000 per year by the district in operating costs as the result of reduced pump lifts and improved conveyance facilities. The present worth value of this saving over the 50-year period would be a direct benefit of $129,000.

Benefits associated with development of a municipal or industrial supply of water are normally based upon the concept of vendability, limited by the next least costly alternative source. This implies that a community will pay whatever cost is necessary to obtain a water supply. For this analysis, municipal and industrial benefits were assumed to be equal to the unit cost of water from the City of Yreka's recently constructed Greenhorn Reservoir. The average annual cost of water from Greenhorn Reservoir was estimated to be $55 per acre-foot, exclusive of costs involved in the distribution system.

Based on estimates of population and future urban demand, the present worth value of total annual municipal and industrial benefits throughout the 50-year period was estimated to be about $1,580,000. The average annual equivalent would be $73,700.

Water-associated recreational benefits from the Grenada Ranch Project were, in terms of dollars per visitor-day, creditable to the project. It was estimated that recreational use at the Grenada Ranch Reservoir would

increase from 6,000 user-days per year in 1970 to 68,000 user-days per year in 2020. These values were determined from estimates of capacity and expected use of camping, picnicking, and boating facilities to be installed at the reservoir. An estimated net value of $1.00 per visitor-day was used in evaluating benefits from visitors using picnic facilities only, and are estimated net value of $2.00 per visitor-day was used in evaluating benefits from visitors using overnight camping facilities. The present worth value of the total recreational benefits that would accrue throughout the 50-year period would be about $1,050,000. The corresponding average annual equivalent benefit would be about $49,000.

A summary of estimated direct benefits creditable to the Grenada Ranch Project are shown in Table 35.

TABLE 35

SUMMARY OF ESTIMATED DIRECT BENEFITS
CREDITABLE TO THE GRENADA RANCH PROJECT

Source of benefit	Direct benefits		
	Total for 50-year period	Present worth	Average annual equivalent
Irrigation			
Reduction of present production costs (Grenada Irrigation District)	$ 300,000	$ 129,000	$ 6,000
Increased productivity (area outside Grenada Irrigation District)	11,320,000	4,062,000	189,100
Subtotals	$11,620,000	$4,191,000	$195,100
Municipal and Industrial			
City of Yreka	$ 4,984,000	$1,401,000	$ 65,200
Other urban communities	732,000	183,000	8,500
Subtotals	$ 5,716,000	$1,584,000	$ 73,700
Recreational	3,258,000	1,055,000	49,100
TOTALS	$20,594,000	$6,830,000	$317,900

Benefit-Cost Ratio

A comparison of total project benefits, with an average annual equivalent value of about $318,000 to the total project costs, with an average annual equivalent value of about $311,000 indicates that the Grenada Ranch Project would have a benefit-cost ratio of 1.02 to 1.0. Although estimated benefits exceed estimated costs, the ratio is small, and this project must be considered marginal under prevailing economic conditions.

Payment Capacity for Irrigation Water

Payment capacity for irrigation water refers to the ability of the water users to pay for irrigation water delivered at the farm headgate. It is computed by subtracting from the gross farm income all costs, including the annual return to the land estimated at five percent of the value of the land. The remaining cost is the amount which can be paid for water.

Annual payment capacities for individual crops in the Grenada Ranch service area, using the same assumptions previously set forth for irrigation benefit estimates, were estimated to vary from $5.75 per acre for barley to $42.30 for potatoes. Considering the crop pattern for the entire service area, the average annual payment capacity for acre for all lands would be $8.05 in 1970, and would increase to $24.70 in the year 2020. These represent average annual payment capacities of $2.40 per acre-foot of water in 1970, and $12.95 per acre-foot of water in the year 2020. The average annual payment capacity throughout the 50-year repayment period would be $9.20 per acre-foot.

Estimated Cost of Delivered Water. Assuming that the costs of the Grenada Ranch Project would be allocated in proportion to the benefits received by each purpose (irrigation, municipal, and recreation), about 60 percent of the costs of the project would be borne by agricultural interests. This would indicate that the average cost of irrigation water would exceed $10.00 per acre-foot.

Gregory Mountain Project

Preliminary studies of the possibilities of developing additional water for use in Shasta Valley indicated that Gregory Mountain Dam and Reservoir should only be considered for development some undetermined time after completion of Grenada Ranch Reservoir. It was shown that construction of the Gregory Mountain Project is not presently warranted from an economic point of view. For this reason, the dam design was not refined beyond preliminary estimates to determine approximate costs. However, a final type design, with full consideration of geologic conditions and standard safety measures, would probably result in costs higher than these presented herein.

Gregory Mountain Reservoir would be created by construction of a dam on the Shasta River, about one mile southwest of Montague, and would have a storage capacity of 77,500 acre-feet. Its operation would provide an additional firm seasonal water supply of about 22,600 acre-feet, over and above that supplied from the Grenada Ranch Reservoir, for use in Shasta Valley. It would also provide the basis for additional enhancement of the recreational potential of Shasta Valley. Principal features of the dam site are shown on Plate 7 "Gregory Mountain Dam on Shasta River"

Topographic maps of the dam and reservoir area at a scale of one inch equals 400 feet, with contour intervals of 10 feet, were prepared during the investigation. Water surface areas and storage capacities of Gregory Mountain Reservoir at various stages of water surface elevation are presented in Table 36.

TABLE 36

AREAS AND CAPACITIES OF GREGORY MOUNTAIN RESERVOIR

Water surface elevation, USGS datum, in feet	Depth of water at dam, in feet	Water surface area, in acres	Storage capacity, in acre-feet
2,457	0	0	0
2,460	3	5	10
2,470	13	55	300
2,480	23	252	1,800
2,490	33	482	5,500
2,500	43	733	11,600
2,510	53	1,323	21,900
2,520	63	2,656	41,800
2,530	73	4,486	77,500

Water Quality

Water released from Gregory Mountain Reservoir would be of good quality and suitable for nearly all beneficial purposes. Concentrations of total dissolved solids and boron would be slightly higher than in water from Grenada Ranch Reservoir but would still fall within the limits of Class II irrigation water. Sodium percentage probably would not exceed

35 percent. Concentrations of other minerals would not exceed the recommended or mandatory limits for domestic water. However, the water might be expected to have an average hardness of about 180 parts per million, which would class it as moderately hard, which would be suitable for agricultural, domestic, or municipal purposes.

Geology

On the basis of the results obtained from preliminary foundation exploration, the Gregory Mountain Dam site appears to be geologically suitable for the construction of an earthfill or rockfill dam. However, careful foundation preparation and treatment would be required to control leakage and to assure stability of the structure.

The dam site is underlain at depth by well-cemented, impervious sandstone and mudstone of Cretaceous age. The Cretaceous bedrock is concealed beneath 45 to 75 feet of unconsolidated to semiconsolidated, poorly sorted sediments of Tertiary age. Except for the basal five to ten feet of pervious sandy gravel, these sediments consist of essentially impervious interbedded clayey gravel, gravelly clay, and sandy clay. Laboratory tests have shown that these clayey sediments have very low shear strength and will be subject to consolidation under additional load. Beneath the channel the Tertiary sediments are covered by about five feet of sandy silt.

The left abutment is formed by a relatively strong but prominently jointed and fractured andesitic lava flow. The base of the flow rests on the Tertiary sediments at about ten feet above the level of the stream bed. The joints, fractures, and scoriaceous (slag) zone combine to make the rock very permeable.

The right abutment is formed by terrace remnants of older alluvial fan deposits which overlap the andesitic flow exposed near the top of the abutment. In section, the terrace deposits appear as a wedge of gravelly silt with hardpan developed near the surface. The maximum depth of the deposit on the abutment is 45 feet. The older alluvium and the andesite are underlain by the Tertiary sediments, which in turn are underlain by the Cretaceous rocks.

Stripping of the left abutment would include removal of soil, talus, and loose-jointed rock to an average depth of three feet. To control leakage through the abutment, a grout curtain would be required, extending downward to the base of the andesite flow and laterally to the saddle. Depth of stripping in the channel would depend on the strength of the Tertiary sediments in place and on the amount of foundation consolidation permitted by the design of the dam. Based on preliminary laboratory tests of the clayey sediments, stripping of weak, unconsolidated sediments to an average depth of about 45 feet would be required under the entire channel section of the dam. Stripping on the right abutment would consist of removing semiconsolidated gravelly silt from a depth of three feet near the top of the dam to 60 feet near the base of the dam.

Depending on the crest elevation of the dam adopted, three or four auxiliary dams would be required, which would be formed on semipervious, unconsolidated older alluvium. The rate of permeability, however, is low enough so that no serious leakage problems would be anticipated at the sites of the auxiliary dams.

A spillway located in the saddle west of the left abutment would be constructed on unconsolidated older alluvium and would require lining

throughout its length. A spillway cut across the hill forming the right abutment would be constructed on jointed volcanic rock and would require partial concrete lining. Spoil from the cut through the right abutment would be suitable for rockfill.

Sources of impervious fill located near the dam site would provide sufficient material to construct a dam at the site. The volcanic rocks adjacent to the abutments could provide sufficient quarry rock for rockfill and riprap. Gravel for aggregate and for drains may be obtained six miles west of the dam site.

Design

Engineering, economic, and geologic conditions, as well as the amount of runoff of the drainage area were considered in selecting the storage capacity of Gregory Mountain Reservoir. However, since studies indicated the reservoir would not be feasible for construction at present, and because Grenada Ranch Reservoir would probably be constructed prior to Gregory Mountain Reservoir, sizing studies of Gregory Mountain Dam and Reservoir were made on a preliminary basis only. For the purpose of presenting costs of the dam and reservoir, a reservoir with a storage capacity of 77,500 acre-feet was selected.

The estimated average seasonal future impaired runoff from the 670 square miles of drainage area above the Gregory Mountain Dam site, for the 35-year base period from 1920-21 through 1954-55, is about 77,800 acre-feet. This future impaired runoff is the amount that would enter the reservoir after the construction and operation of Grenada Ranch Reservoir.

However, not all of this runoff could be conserved, because of fishery maintenance requirements and economic limits of reservoir storage capacity.

Estimates of the amount of new firm seasonal yield from Gregory Mountain Reservoir were determined from monthly operation studies. In conducting these studies consideration was given to prior rights and fishery maintenance requirements. Prior rights not satisfied by water entering the stream from the drainage area below the dam were satisfied by reservoir releases. The maximum releases for these prior rights were limited to the amount of inflow into the reservoir. Fishery maintenance flows not satisfied by these releases would be satisfied by a plan similar in operation to that previously described for the Grenada Ranch Reservoir.

A minimum dead storage allowance of 2,900 acre-feet was used in the operation studies. This amount was assumed to be sufficient to allow for sedimentation during the economic life of the project and minimum storage for recreational purposes. The studies indicated that during the 35-year base period, the reservoir could be expected to be drawn down to dead storage during the recreation season less than one percent of the time.

The estimate of monthly distribution of seasonal demand for water from Gregory Mountain Reservoir was made in accordance with the values of monthly percentages of seasonal irrigation demand previously described. The monthly schedules of required fishery maintenance flows, and the maximum, average, and minimum flows available for fish under project conditions, would be very similar to those described for the Grenada Ranch Project.

A seasonal summary of the operation study, including estimates of the resultant flow available for fish, is presented in Table 37.

TABLE 37

SEASONAL SUMMARY OF GREGORY MOUNTAIN RESERVOIR OPERATION STUDY

(In acre-feet)

Season	Impaired inflow[a]	Inflow from up-stream irrigation[b]	Net evaporation	Project yield	Downstream releases for prior rights and fishery maintenance	Spill	Storage at end of season (Sept. 30)	Resultant fl[ow] for fishery maintenance, Shasta Rive[r] above conflue[nce] with Yreka Cr[eek]
1920-21	128,300	3,300	6,500	22,600	43,800	33,700	65,200	83,100
22	86,400	3,300	8,100	22,600	52,000	12,300	59,900	68,200
23	75,700	3,300	7,800	22,600	48,000	3,900	56,600	57,500
24	50,000	3,300	6,200	22,600	40,000	0	41,100	42,200
25	54,300	3,300	5,000	22,600	32,600	0	38,500	37,000
26	65,400	3,300	4,200	22,600	55,600	0	24,800	58,700
27	105,500	3,300	5,500	22,600	37,800	9,000	58,700	55,500
28	96,200	3,300	7,500	22,600	50,900	20,500	56,700	76,400
29	57,100	3,300	7,600	22,600	34,400	0	52,500	38,000
30	52,400	3,300	7,500	22,600	23,400	0	54,700	29,800
1930-31	39,400	3,000	6,300	20,800	26,500	0	43,500	29,100
32	37,600	3,100	4,700	21,000	26,100	0	32,400	29,200
33	36,900	3,300	3,100	22,400	25,600	0	21,500	28,800
34	31,200	3,300	1,900	22,600	24,000	0	7,500	26,200
35	36,900	2,200	1,300	14,600	26,300	0	4,400	28,700
36	41,600	3,300	1,400	21,600	22,800	0	3,500	27,800
37	40,600	3,300	1,100	21,000	22,400	0	2,900	26,000
38	141,600	3,300	10,200	22,600	29,500	14,500	71,000	51,600
39	74,900	3,300	7,100	22,600	52,200	9,300	58,000	64,700
40	86,700	3,300	8,100	22,600	28,700	24,100	64,500	61,100
1940-41	147,100	3,300	8,500	22,600	43,700	71,000	69,100	119,700
42	167,000	3,300	8,400	22,600	46,400	93,800	68,200	146,100
43	77,600	3,300	8,000	22,600	51,800	8,300	58,400	66,500
44	63,800	3,300	6,400	22,600	51,500	0	45,000	54,700
45	60,300	3,300	4,800	22,600	44,400	0	36,800	50,400
46	79,200	3,300	4,500	22,600	51,000	0	41,200	58,300
47	46,800	3,300	4,000	22,600	36,600	0	28,100	39,600
48	55,200	3,300	3,000	22,600	34,700	0	26,300	39,200
49	73,500	3,300	2,700	22,600	52,800	0	25,000	57,000
50	61,900	3,300	2,600	22,600	41,100	0	23,900	45,800
1950-51	102,900	3,300	5,000	22,600	44,100	0	58,400	49,800
52	117,700	3,300	8,500	22,600	44,900	42,500	60,900	93,600
53	149,100	3,300	8,200	22,600	41,700	76,700	64,100	125,000
54	116,500	3,300	7,600	22,600	47,600	49,200	56,900	101,600
55	66,400	3,300	7,600	22,600	56,200	0	40,200	59,100
35-year base period average	77,800	3,200	5,700	22,200	39,700	13,400	43,400	57,900

a. Flow impaired by present use and operation of Grenada Ranch Project.

b. Assumed portion of irrigation return flow which would enter reservoir and be available for re-use.

As a result of preliminary sizing studies, a compacted earthfill dam, with a height of 83 feet above stream bed and a crest elevation of 2,540 feet, U. S. Geological Survey datum, was selected to illustrate the cost of Gregory Mountain Dam and Reservoir. The dam would have a crest length of about 1,025 feet and a crest width of 30 feet, and would have upstream and downstream side slopes of five to one and three to one, respectively. Since the construction materials are relatively impervious, a vertical drain in the fill section would be used to alleviate seepage forces in the downstream portion of the dam. A well-graded transition zone between the drain and the homogeneous fill would act as a filter to prevent piping. The volume of fill would be about 877,000 cubic yards.

Four auxiliary dams would be required. Auxiliary dams No. 1 and No. 3 would be in saddles about 2,000 feet east and about 1,500 feet west of the main dam, respectively. These dams would be similar in design to the main dam, and would have maximum heights above natural ground of about 15 and 20 feet, respectively. Each would require a volume of fill of about 155,000 cubic yards. The lower portions of the embankments would extend from five to ten feet below normal pool elevation. Auxiliary dams No. 2 and No. 4 would be located in saddles about 1,000 feet east and 600 feet west of the main dam, respectively. They would be required for freeboard purposes only and would be of homogeneous earthfill construction, with side slopes of 2.5 to 1.

The standard project and maximum probable floods at the Gregory Mountain site, after giving consideration to a reduction by temporary storage in the existing upstream Dwinnell and proposed Grenada Ranch

reservoirs, were estimated to have peak flows of 27,700 and 46,200 second-feet, respectively. A gated, concrete spillway structure would be located on the right abutment at the axis of the main dam. The spillway discharge channel would be concrete lined for the first 300 feet below the weir. The remaining 1,150 feet of unlined channel would enter the Shasta River about 850 feet downstream from the toe of the dam. The spillway crest would be placed at an elevation of 2,509 feet, U. S. Geological Survey datum, and would have a net weir length of 100 feet. Three radial gates, 21 feet in height and 33-1/3 feet in width, would be installed to control downstream flood releases. The gates would be approximately counter-balanced, and designed for automatic hydraulic operation, power operation, and manual operation. Normal pool elevation in the reservoir would extend to the top of the gates at an elevation of 2,530 feet, leaving ten feet total free-board between the top of the gates and the crest of the dam. As a result of routing the maximum probable flood, it was estimated that with the radial gates fully open, the peak spillway discharge from Gregory Mountain Reservoir would be about 40,500 second-feet; and the maximum surcharge in the reservoir would be about 26 feet, which would leave a residual freeboard of five feet between the maximum water surface elevation and the crest of the dam.

The outlet works at the dam would consist of a 54-inch diameter reinforced concrete pipe, placed in a trench beneath the dam, and a 54-inch diameter corrugated metal pipe from the toe of the dam to the Shasta River. Emergency shutoff of the outlet pipe would be accomplished by operation of gate valves, contained in a submerged intake structure located at the up-stream toe of the dam. Normal releases from the reservoir for prior rights and fishery maintenance would be controlled by a 42-inch, hydraulically operated, butterfly valve located just below the dam.

The land within the Gregory Mountain Reservoir service area is presently utilized by dairy and stock ranches for irrigated and nonirrigated crops, pasture, and residential purposes. At the normal pool and dam crest elevations about 4,500 and 6,500 acres, respectively, would be inundated. Clearing of trees, brush, and improvements would be required below the normal pool elevation. The improvements in the area consist of buildings for about 30 ranches. About seven miles of paved county road, 5.5 miles of the Southern Pacific Railroad, 11 miles of power transmission and distribution lines, 5.5 miles of coaxial telephone cable, and 7.5 miles of telephone exchange lines would require relocation.

Economic studies of the Gregory Mountain Project showed that complete design of a conveyance and distribution system was not warranted at this time. However, it would probably be advantageous to have an arrangement similar to that described for the Grenada Ranch Project, wherein water would be pumped directly from the reservoir for service to areas north and south of Shasta River. Because the Shasta River Water Users Association's pumping plant would be inundated by the reservoir, and would have to be replaced, the project plants would have sufficient capacity to pump the association's irrigation water, as well as the new project yield. Because the new seasonal yield of the Gregory Mountain Project would be of the same magnitude as that of the Grenada Ranch Project it was assumed that cost of distribution facilities would also be of the same order of magnitude.

The recreation potential at the Gregory Mountain Reservoir would be somewhat better than that for the Grenada Ranch Reservoir, because seasonal drawdown and lateral withdrawal of the shoreline would not be so drastic. Public recreation facilities, similar to those at Grenada Ranch

Reservoir, would be provided as an integral part of the project. The expected use and staging of the required recreational facilities would depend on the time lapse between construction of the two projects.

The Gregory Mountain Project would have even greater adverse effects on the Shasta River fishery resources than the Grenada Ranch Project, principally from losses of additional spawning area above the dam. To compensate for this loss, trapping facilities similar to those described for the Grenada Ranch Project would be installed at the base of the dam, and the hatchery facilities at the existing Mount Shasta Fish Hatchery would be enlarged to provide a greater capacity than those required for the Grenada Ranch Project.

General features of the Gregory Mountain Dam and Reservoir are listed in Table 38.

Project Costs

The capital cost of the Gregory Mountain Project was estimated to be about $10,500,000. Of this cost, $8,840,000 would be for the dam and reservoir; at least $1,400,000 would be for the conveyance and distribution system; $135,000 would be for the fishery maintenance facilities; and $173,000 would be for recreation facilities. The $8,840,000 for the dam and reservoir would include approximately $5,000,000 for land acquisition, clearing and relocation costs, including engineering and contingencies. Since the project was found to be not economically justified for construction in the foreseeable future, estimates of average annual costs are not presented in this report.

It should be re-emphasized that the design upon which the cost estimates were developed was not refined beyond a very preliminary stage.

TABLE 38

GENERAL FEATURES OF GREGORY MOUNTAIN DAM AND RESERVOIR ON SHASTA RIVER

Characteristics of Site	
Drainage area, in square miles	670
Estimated average seasonal impaired runoff after construction and operation of Grenada Ranch Project, in acre-feet	77,800
Estimated average seasonal net depth of evaporation, in feet	1.97
Elevation of stream bed, USGS datum, in feet	2,457
Main Dam	
Type	impervious compacted earthfill
Crest elevation, USGS datum, in feet	2,540
Crest length, in feet	1,025
Crest width, in feet	30
Side slopes	
Upstream	5 to 1
Downstream	3 to 1
Volume of fill, in cubic yards	877,000
Height of spillway lip above stream bed, in feet	52
Height of radial spillway gates, in feet	21
Normal pool elevation, USGS datum, in feet	2,530
Freeboard above spillway lip, in feet	31
Freeboard above top of spillway gates, in feet	10
Auxiliary Dams	
Number required	4
Types	impervious rolled earthfill, with and without drains
Crest elevation, USGS datum, in feet	2,540
Total crest length, in feet	3,500
Maximum height above natural ground, in feet	20
Volume of fill, in cubic yards	149,000
Reservoir	
Surface area at normal pool elevation, in acres	4,500
Gross storage capacity at normal pool elevation, in acre-feet	77,500
Dead storage capacity, in acre-feet	2,900
Active storage capacity, in acre-feet	74,600
Type of spillway	gated ogee weir with partially lined chute
Net crest length of spillway, in feet	100
Spillway discharge capacity, with gates fully open and with 5-foot residual freeboard, in second-feet	40,500
Spillway discharge capacity, over top of gates without overtopping the dam, in second-feet	10,000
Net firm seasonal yield, in acre-feet	22,600[a]

a. After making allowances for releases for prior rights and fishery maintenance and assuming a maximum seasonal deficiency of 35 percent and an average seasonal deficiency not exceeding 2 percent.

Because of the unfavorable economics of the project, refinements of design were not considered to be warranted. Such refinements would entail solutions for the following problems: (1) If the gated overpour spillway, as shown on Plate 7, were chosen, the weir should be located at the axis of the dam. This would create a large amount of additional excavation in the approach channel. An ungated side channel spillway might be a better solution to this problem. Channel lining and a stilling basin, or a flip bucket, might be needed to prevent erosion. (2) Foundation leakage resulting in piping would be a problem. Upstream blanketing might be a solution to this. (3) The filter and embankment would have to be carefully designed to prevent settlement of the unconsolidated material in the foundation. (4) Stability analysis and soils tests would have to be run to determine the most economic stable section. If and when these and other design problems are solved, the cost of constructing a dam at this site might prove to be higher than those shown in the preceding paragraph.

Project Benefits

The direct benefits that would accrue to the Gregory Mountain Project would be derived from the increased water supply provided therefrom, and from increased recreational activity made possible by the project.

If built, the Grenada Ranch Project would be capable of supplying all the municipal and industrial supplemental water requirements within its service area for the foreseeable future. Therefore, the water supply from the Gregory Mountain Project would be used primarily for irrigation purposes. The Gregory Mountain Project would add an additional increment of new seasonal yield of 22,600 acre-feet of water per season.

Because of the relatively poorer quality of agricultural lands that would be served by the Gregory Mountain Project, irrigation benefits derived would be of a lesser value per acre, or per acre-foot of water, than irrigation benefits derived from water supplied from the Grenada Ranch Project. In addition, the cost of the Gregory Mountain Project would greatly exceed the cost of the Grenada Ranch Project. Even on the optimistic assumption that benefits derived from the Gregory Mountain Project would be equal to those from the Grenada Ranch Project, and on the basis of the previously estimated costs and yields, the benefit-cost ratio for the Gregory Mountain Project would be only about 0.3 to 1.0. For this reason, more detailed benefit-cost estimates were not developed for the Gregory Mountain Project.

Montague Project

Montague Project was studied as a possible alternative to Gregory Mountain Dam and Reservoir. The two possible dam sites considered for Montague Dam are located within a quarter-mile reach of the Shasta River, about five miles below the Gregory Mountain site, as shown on Plate 8 "Geologic Map Upper and Lower Axis Montague Dam Site". The 60 square miles of drainage area between the Montague and Gregory Mountain sites produce little additional runoff. Comparable sizes of reservoirs at these two sites would have comparable storage and yield capacities.

Topographic maps of the Montague dam sites, at a scale of one inch equals 100 feet, with a contour interval of five feet, and of the reservoir area at a scale of one inch equals 400 feet with a contour interval of ten feet, were prepared during the investigation. Water surface

areas and storage capacities of Montague Reservoir at various stages of water surface elevation with dams at either the upper or lower sites, are presented in Table 39.

Preliminary subsurface foundation exploration drilling was conducted at each of the axes considered for Montague Dam. The core samples taken showed that geologic conditions are unfavorable for construction of any type of dam. Wide gouge and breccia zones with low shear strength exist along faults in the channel. The abutments would consist of weak, brecciated serpentine and pods of metadiorite overlain by locally pervious terrace deposits. The construction of an earthfill dam at either site would necessitate very extensive and costly foundation treatment. For this reason, further planning for the Montague Project was abandoned.

Details of the subsurface exploration program and geology of the Montague Dam site are on file with the Department of Water Resources.

Klamath River Import Project

Even with the maximum possible development of the waters of the Shasta River, it would be necessary to import water from outside sources in order to meet the possible ultimate water requirements of Shasta Valley. The principal nearby external source of water that could be made available for use in Shasta Valley is the Klamath River.

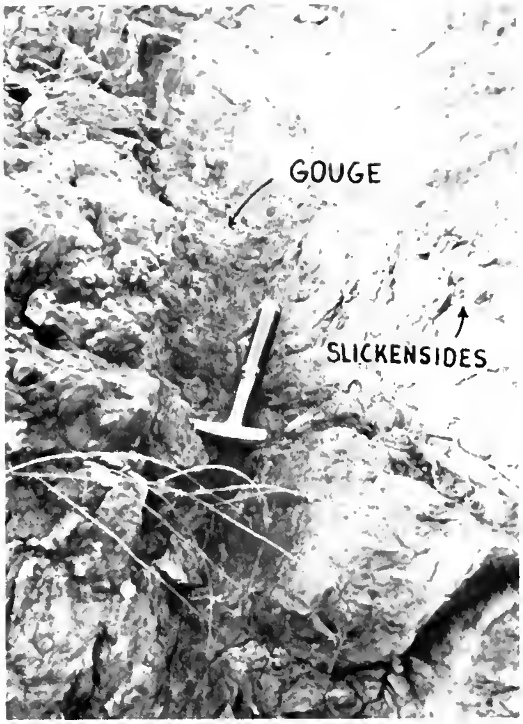
Prior Plans for Importation of Water

Plans for developing the waters of the Klamath River for use in Shasta Valley are not new. The first recorded importation survey of Klamath River waters was made by the United States Reclamation Service in 1905,

TABLE 39

AREAS AND CAPACITIES OF
MONTAGUE RESERVOIR

Water surface elevation, USGS datum, in feet	Depth of water at dam, in feet	Water surface area in acres	Storage capacity, in acre-feet
2,403	0	0	0
2,410	7	7	20
2,420	17	52	310
2,430	27	265	1,900
2,440	37	481	5,600
2,450	47	687	11,500
2,460	57	952	19,700
2,470	67	1,178	30,300
2,480	77	1,666	44,500
2,490	87	2,078	63,300
2,500	97	2,672	87,000
2,510	107	3,961	120,200



Shear along fault zone in the vicinity of Montague Dam site.

Contorted schist on fault contact in the vicinity of Montague Dam site.

but no projects were undertaken as a result of the survey. In 1921 the Klamath-Shasta Valley Irrigation District was organized for the purpose of making a comprehensive study of irrigation possibilities in Shasta Valley, and of possible diversion and conveyance works from the Klamath River. The results of the investigation disclosed that costs of such works would be excessive, and the Klamath-Shasta Valley Irrigation District was dissolved in January 1924.

A plan to import water from the Klamath River to Shasta Valley was more recently reported in Department of Water Resources Bulletins No. 3 "The California Water Plan", and No. 83 "Klamath River Basin Investigation". These investigations indicated that a diversion structure which included hydroelectric power generation, and located near Iron Gage on the Klamath River, would hold some promise. More detailed studies of the project were recommended. This project, as envisioned in Bulletins Nos. 3 and 83, would consist of an Iron Gate Dam and Reservoir on the Klamath River, Iron Gate Pumping Plant, Ager Pumping Plant, Red School Dam and Reservoir, and a Bogus Conduit. The project would provide a regulated seasonal supply of new firm water of about 122,000 acre-feet, of which 20,000 acre-feet would be utilized in the Ager area and the remaining 102,000 acre-feet in Shasta Valley.

The capital cost of the Shasta Valley Import Project (as reported in Bulletin No. 83) was estimated to be $19,960,000, with annual costs of approximately $1,415,000. An additional $522,000 per year would be required for pumping. This total annual cost of $1,937,000 could be expected to deliver Klamath River water to Shasta Valley at a unit cost of approximately $16 per acre-foot, exclusive of costs for a local distribution system.

Present Plans for Iron Gate Dam and Reservoir

Since the preparation of Bulletins Nos. 3 and 83, the California-Oregon Power Company, largely through the efforts of the California Department of Fish and Game, has undertaken construction of Iron Gate Dam and Reservoir for the combined purposes of power generation and stream flow regulation for fish. Power requirements of the California-Oregon Power Company require sudden changes in the release of water from Copco Lake, coincident with power requirement peaks at certain hours of the day. These sharply fluctuating releases have long been considered a hazard to both anglers and fish in the Klamath River and, over the years, have allegedly resulted in the stranding of thousands of fish on the banks of the Klamath River and the drowning of a number of anglers who were fishing the river.

As planned by COPCO, Iron Gate Dam will be an earthfill structure with a compacted, impervious clay core, with a concrete cutoff wall and grout curtain at its base. Located on the Klamath River, about seven miles downstream from the existing Copco Dam, as shown on Plate 5, Iron Gate Dam will raise the reservoir level to the tailwater elevation of COPCO No. 2 powerplant. The top of the dam will be approximately 173 feet above stream bed, with a crest elevation of 2,338 feet (United States Geological Survey datum) and a crest length of about 860 feet, including the spillway section. The spillway section, with a crest length of 175 feet, will be a concrete structure equipped with five radial Tainter gates, each 12 feet in height and 30 feet in width, with a total discharge capacity of about 32,000 second-feet. The reservoir will have a storage capacity of about 58,000 acre-feet, at a normal pool elevation of 2,328 feet (United States Geological Survey datum). The powerplant will be located

downstream from the base of the dam, on the south bank of the Klamath River, and will contain a vertical reaction turbine rated at 25,000 horsepower, connected directly to a 6.9 kilovolt generator rated at 18,000 kilowatts. Power generation releases of water from the reservoir will pass through a 12-foot diameter power conduit and penstock to the powerhouse. The average annual energy generated, as estimated by COPCO will be about 150,000,000 kilowatt-hours. Releases for stream flow regulation will pass through a 16-foot diameter tunnel through the right abutment.

Fishery Aspects. As a result of litigation between the California Department of Fish and Game and the California-Oregon Power Company, an agreement was negotiated in 1959 with respect to the Iron Gate development. This agreement provides:

> "...that COPCO shall release a minimum flow of not less than 710 second-feet of water into the natural channel of the Klamath River, that the rate of fluctuation of flows of the Klamath River below the said Iron Gate development shall not exceed 250 second-feet of water per hour and that the change in river stage or elevation shall not exceed three inches per hour whichever produces the least amount of fluctuation."

The complete terms of this agreement are presented in Appendix C, "Agreements".

Water Rights Restrictions. Protests to COPCO's application, before the California State Water Rights Board, for a permit to use of water for the proposed Iron Gate development, were submitted by the California Department of Fish and Game, California Department of Water Resources, and California Klamath River Commission. These protests were subsequently satisfied and water rights permit order number 136 was issued

to the applicant, enabling COPCO to proceed with the Iron Gate development. Of significant importance to plans for importation of water to Shasta Valley is the stipulation, initiated by the Department of Water Resources, wherein COPCO's water rights at Iron Gate for power purposes are subject and subordinate to prior or subsequent water rights for diversion of water from the Klamath River for use in the Shasta Valley-Ager area for higher uses such as municipal, domestic, or irrigation. This stipulation is applicable to a maximum seasonal diversion of 220,000 acre-feet per year, provided that, until March 1, 2006, and subject to vested rights, if any, the water rights to which the permit is subordinate shall be upon the following conditions:

> (a) The maximum amount to be diverted shall not exceed 120,000 acre-feet in any water year (October 1 to September 30), and the maximum rate of diversion shall not exceed 300 cubic feet per second from May 16 to September 15 of each year, and 100 cubic feet per second from September 16 of each year to May 15 of the succeeding year; and
>
> (b) Permittee under any future appropriation will make, or will have made, due compensation, fixed either by agreement with the present permittee or by eminent domain proceedings, for the right to enter upon or use any facilities of the present permittee, including the right to use any reservoir created by the present permittee as a point of diversion. This subsection shall not be deemed to imply that any person has a right to enter upon or use any facilities of the present permittee without making due compensation.

A copy of the water rights permit, including all of its terms and conditions, is presented in Appendix C.

Future importation of Klamath River water from the Iron Gate site to the northerly boundary of the Shasta Valley service area would require about 23 miles of canal. The static pump lift, from stream bed elevation of about 2,165 feet at the downstream toe of Iron Gate Dam to an elevation of 2,800 feet in Shasta Valley, would be about 635 feet. An additional

pumping head, estimated to vary somewhere between 1.5 and 2.5 feet per mile of canal, depending on the design capacity of the canal, would be required to overcome head loss due to the frictional resistance of the conduit to the flow of water. On the basis of COPCO's agricultural pumping service rate schedule, cost of electric energy required for pumping would be on the order of six to seven dollars per acre-foot.

If water were pumped directly from Iron Gate Reservoir, currently being constructed by COPCO, the required pumping head could be reduced by about 160 feet. The pumping cost would be reduced proportionately. However, it is emphasized that although the stipulation in COPCO's water rights permit would give preference to applications for higher use in the Shasta Valley-Ager area so far as water rights are concerned, the stipulation does not give a potential diverter the right to trespass on COPCO's property without consent and due compensation. The best course of action would have to be determined at the time that Shasta Valley interests are ready to proceed with an import project. For this reason, and because it was apparent from reconnaissance studies that the import project would not be feasible in the foreseeable future, a definite plan for importation, and costs thereof, was not included within the scope of this investigation.

Financing of Local Projects

In order to proceed with construction of the local projects, an adequate type of organization would be necessary to execute the required contractual obligations and to undertake the responsibilities of construction, operation, and maintenance of the project. There are numerous types of districts empowered to construct and operate water projects. Such districts can be formed to embrace either an entire project service area or all project service areas within Shasta Valley. Once established, such districts would have available a number of sources of funds from state and federal programs.

The source of funds, and the attendant interest rates at which capital may be borrowed, is of prime importance in long-term financing. In this regard, it is probable that private capital could be attracted only at extremely high interest rates for the financing of local water projects such as those investigated in this report.

Under present law, at least three sources of funds are available under which capital funds may be obtained for the study of and/or construction of water projects in Shasta Valley. These are (1) the State Government under the terms of the Davis-Grunsky Act, (2) the Federal Government under provisions of the Small Reclamation Projects Act of 1956, Public Law 984, 84th Congress and (3) the Watershed Protection and Flood Prevention Program of 1954, Public Law 566, 83rd Congress, as amended. Each of these is discussed below.

Davis-Grunsky Act. Under the terms of the Davis-Grunsky Act, the Department of Water Resources, with prior approval of the California Water Commission, is authorized to make loans of up to $4,000,000 to public

agencies for the construction of qualified local water projects. Loans under this act would bear interest at a rate equal to the net interest cost to the State on the last sale of general obligation bonds of the State, or the multiple of one-quarter of one percent next above the applicable net interest cost if it is not a multiple of one-quarter of one percent. The applicable interest rate, as of this time, (1961) is less than 4 percent. In effect, this bill substitutes state credit for local credit, which may result in lower interest costs to local agencies than might otherwise be possible.

In the interest of recreation, the department is also authorized to make state grants not exceeding $300,000, toward the cost of the dam and reservoir for any one project, subject to the provisions of the act and the prior approval of the California Water Commission.

Under the Davis-Grunsky program loans in excess of $4,000,000, and grants in excess of $300,000, would require specific authorization by the Legislature.

The sponsoring local agency is responsible for planning, constructing, operating, and maintaining the project. In addition to certain basic conditions of eligibility, approved projects must be found by the department to be engineeringly feasible and economically justified.

<u>Small Reclamation Projects Act of 1956, Public Law 984</u>. This program is administered by the United States Bureau of Reclamation. Under the program, states, or political subdivisions thereof, including certain water districts, can obtain loans for the construction of small reclamation projects <u>primarily</u> for irrigation purposes. Nonreimbursable federal grants may also be made for the flood control and fish and wildlife functions of the project, but not for recreation.

The program is limited to projects costing less than $10,000,000. The maximum federal contribution to the project, in the form of loans and grants, is limited to $5,000,000. Repayment of the project cost assigned to the irrigation of lands not in excess of 160 acres in a single ownership is free of interest charges. However, interest is charged on the other reimbursable portions of the project costs. The interest rate is based on the long term obligations of the United States which is currently 3-3/8 percent (1961).

The applicant organization is responsible for planning, constructing, operating, and maintaining the proposed project. It must also provide, at its own expense, all lands and rights of way and all water rights. Each application must be accompanied by a check of $1,000 to cover part of the cost of the review and processing of the application. The cost of administration by the Bureau of Reclamation must be paid by the applicant.

Watershed Protection and Flood Prevention Act of 1954, Public Law 566. This program is administered by the Soil Conservation Service of the United States Department of Agriculture. Under it, the federal government will pay for works of improvement in watersheds applicable to flood prevention, for a part of the cost of works of improvement for irrigation, drainage, and other agricultural water management, for part of the cost of fish and wildlife development, and will give planning assistance to the public agency constructing the project. The program is limited to projects in watersheds smaller than 250,000 acres (390 square miles) that do not include structures having a capacity of more than 5,000 acre-feet for flood prevention, or a capacity of more than 25,000 acre-feet for all purposes.

The local agencies are required to pay for installing improvements for purposes other than flood prevention and agricultural water management,

and for the cost of all lands, easements, and rights-of-way needed for the project. It may be noted that under the California Watershed Protection and Flood Prevention Law (Section 12865 of the Water Code), the State will reimburse the local agency for the required local contribution for the cost of lands, easements, and rights-of-way, if the Department of Water Resources finds that the benefits of the project exceed the costs.

CHAPTER V. CONCLUSIONS AND RECOMMENDATIONS

As a result of field investigation and analysis of available data on the water resources and water problems of Shasta Valley, made in accordance with the procedures and assumptions discussed in this bulletin, the following conclusions have been reached:

Conclusions

1. Expansion of the present economy of Shasta Valley, which is based largely on agriculture, principally the raising of livestock, and on lumbering and recreation will be handicapped without development of additional water supplies.

2. Mean seasonal runoff from the Shasta River Basin totals about 171,000 acre-feet, of which 65 percent, or about 112,000 acre-feet, now wastes from the basin.

3. Surface and ground water supplies of the Shasta River Basin are generally of good to excellent mineral quality and are suitable for most beneficial purposes.

4. The estimates of present and probable ultimate mean seasonal water requirements of the Shasta River Basin are on the order of 107,000 acre-feet and 381,000 acre-feet, respectively.

5. There are about 141,000 irrigable acres within Shasta Valley, of which about 39,200 acres (28%) are now under irrigation. It is anticipated that when full development is reached about 105,000 acres (75%) will be under irrigation.

6. The estimates of present and probable ultimate mean seasonal supplemental water requirements of the Shasta River Basin are on the order of 25,000 and 299,000 acre-feet, respectively.

7. Existing developed sources of water supply for the City of Yreka, including that from the newly constructed Greenhorn Dam and Reservoir, should meet the needs of a population of about 6,400 people, which population may be reached by 1970. At such time, the city will have to seek additional sources of water to meet its supplemental water requirements, estimated to be about 3,800 acre-feet annually by the year 2020.

8. In addition to consumptive water requirements there are substantial requirements in the Shasta River for maintenance of stream flow to support fish life. To that end the California Department of Fish and Game has recommended that flows aggregating 66,000 acre-feet per year be maintained in the Shasta River below its confluence with Yreka Creek.

9. The Grenada Ranch Project, creating 22,400 acre-feet of storage capacity on the Shasta River, seven miles downstream from Dwinnell Reservoir, would be the most economical water development of those investigated during the Shasta Valley Investigation. The project would produce a firm, annual water supply of about 22,200 acre-feet, sufficient to meet the estimated supplemental municipal and industrial water demands of the Shasta River Basin for the next 60 years and provide for the irrigation of about 9,000 acres of agricultural lands.

10. The estimated capital cost of the Grenada Ranch Project, based on 1959 price levels, is about $3,760,000. Average annual cost over the 50-year repayment period at four percent interest would be about $311,000. The estimated average annual unit cost of new water yield would be about $14 per acre-foot, including costs of distribution.

11. The average annual equivalent direct benefits creditable to the Grenada Ranch Project would be about $318,000, accruing to the project

purposes as follows: irrigation, \$195,000; municipal and industrial water supply, \$74,000; and recreation, \$49,000.

12. While the Grenada Ranch Project would have an indicated benefit-cost ratio of 1.02 to 1.0, the ratio is so near unity that the project must be considered unwarranted under prevailing economic conditions and private capital financing as considered herein.

13. Following possible future development of the Grenada Ranch Project, the Gregory Mountain Project designed to store 77,500 acre-feet of water now appears to offer the next best opportunity for development of additional water supplies in the Shasta River Basin. The Gregory Mountain Project would provide an additional firm seasonal water supply of about 22,600 acre-feet, over and above that from the Grenada Ranch Project.

14. The estimated capital cost of the Gregory Mountain Project, based on 1960 price levels, is about \$11,200,000. More than \$5,000,000 of this cost would be for land acquisition, clearing, and relocation of public and private transportation, communication, power, and water supply facilities.

15. Direct benefits creditable to the Gregory Mountain Project would be less than those from the Grenada Ranch Project. Moreover, the cost of the Gregory Mountain Project would greatly exceed that of the Grenada Ranch Project. Therefore, the Gregory Mountain Project would not be economically justified under prevailing economic conditions.

16. Geologic conditions are unfavorable for construction of a dam at the Montague site, an alternative to the Gregory Mountain site.

17. With maximum conservation of the water resources of the Shasta River, the yield developed would be far less than the estimated ultimate supplemental water requirements of the Shasta River Basin. If possible future requirements are to be fully met, importation of water from sources outside the basin will be required.

18. The Klamath River appears to offer the best source of water for importation into Shasta Valley. The water rights permit issued to the California-Oregon Power Company for its Iron Gate Power Project, now (1961) under construction, contains a reservation permitting the use of Klamath River water in the Shasta Valley-Ager area. This reservation is limited to an eventual diversion of 220,000 acre-feet of water per season from the Klamath River to the Shasta Valley-Ager area.

19. Estimates of cost to import 122,000 acre-feet of water per year from the Klamath River to Shasta Valley, were reported in Bulletin No. 83, "Klamath River Basin Investigation". The capital cost, based upon prices prevailing in the fall of 1958, was estimated to be about $20,000,000, with annual costs of about $1,400,000. The estimate of unit annual cost of water was about $16 per acre-foot.

20. The combined yield of 44,800 acre-feet of new water seasonally from the Grenada Ranch and Gregory Mountain Projects, together with the possible eventual seasonal importation of 220,000 acre-feet of water from the Klamath River, would satisfy about 90 percent of the estimated ultimate supplemental requirement of about 300,000 acre-feet in the Shasta River Basin.

21. Methods of financing which may be applicable to local projects in Shasta Valley, other than financing with private capital borrowed by a district, include: (1) the provisions of the Davis-Grunsky Act administered by the State Department of Water Resources, (2) the provisions of the Small Reclamation Projects Act of 1956, Public Law 984, administered by the United States Bureau of Reclamation, and (3) the provisions of the Watershed Protection and Flood Prevention Program of 1954, Public Law 566, administered by the Soil Conservation Service of the United States Department of Agriculture.

Recommendations

As a result of studies conducted under the Shasta Valley Investigation and the conclusions presented herein, it is recommended that:

1. Local interests consider construction of the Grenada Ranch Project only at such time, and under such economic conditions and method of financing, as would give rise to a satisfactory benefit-cost ratio.

2. Recreation needs be a primary consideration in future planning for the Grenada Ranch Project with due regard for municipal, industrial, and irrigation requirements of Shasta Valley.

3. In developing the waters of the Shasta River, adequate provision be made for maintenance of the salmon and steelhead fishery.

4. A local district be formed to explore all possible methods of financing local water developments in Shasta Valley.

5. The future program for developing water supplies to serve Shasta Valley be based on periodic review of project feasibility by appropriate public agencies.

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APPENDIX A

GEOLOGY OF SHASTA VALLEY

(SHASTA RIVER BASIN)

TABLE OF CONTENTS

FOREWORD

A number of geologists have worked in the Shasta River Basin and have produced an impressive body of literature concerning its geologic history and structure. This appendix attempts to summarize some of the information available and present to the reader, who may practice some other profession, a picture of the basin and cradled valley within. Whatever is of merit herein belongs to those who have walked through the area, studied it and written down their findings. A short bibliography which will provide more extensive and intensive information on the subject is included.

The plate accompanying this appendix, Regional Geologic Map, Shasta Valley Area, shows the locations and extent of the various formations discussed and will enable the reader to orient himself with respect to the major topographic and cultural features of the area.

Land Forms

Shasta Valley and its drainage basin consist of a structural and topographic depression between the Klamath Mountains to the west and the Cascade Range to the east. The valley and the two surrounding mountain ranges make up three areas that are marked by widely differing land forms. The floor of the valley varies in elevation from 2,400 to 2,800 feet above sea level and is occupied by some rather unusual land forms that give the landscape its unique appearance. The Klamath Mountains are complex both in form and structure with rugged ridges and peaks rising as high as 9,000 feet above sea level. The Cascade Range consists of a north-trending chain of large dormant and/or extinct volcanoes, dominated by Mount Shasta, which rises 14,161 feet above sea level.

Shasta Valley: The floor of Shasta Valley may be subdivided into four areas having rather distinct land forms. These are (1) the gentle, eastward sloping alluvial plain along the western part of the valley, (2) the hillock and flat area in the trough of the valley, (3) the recent basalt flow which covers the southeasterly quarter of the valley, and (4) the gently rolling, old, coalescing alluvial fans that cover the north end of the Shasta Valley.

(1) The eastward sloping plain is relatively featureless, having been formed by the recent deposition of alluvium along several streams flowing from the west. These alluvial deposits form broad but rather indistinct alluvial fans along an area extending from the Shasta River at the southwestern end of the valley, and northward along U. S. Highway 99 to the vicinity of Grenada. A long narrow arm of these deposits extends northwestward from Grenada to Yreka. Most of the alluviated area consists of well-drained, good quality agricultural land. These alluvial fans gradually merge to the east with the hillocks, ridges, and poorly drained flats which occupy the trough of the valley.

(2) The hillock and flat area is the most striking of the various subareas comprising Shasta Valley. It consists of older volcanic rocks, eroded into a myriad of hillocks, protruding from a few feet to 800 feet above the valley floor. Most of these hillocks are cone and dome-shaped; some are mesas, and a few are long hogback ridges. Together they form an unusual landscape deceptively like the products of recent volcanic activity. The hillock and flat area extends from the southern end of the valley near Edgewood, northward to Montague, along the trough of the valley.

(3) The basalt flow, called the Pluto's Cave basalt, covers the southeasterly quarter of Shasta Valley. This flow erupted from the flanks of Mount Shasta during the present or Recent epoch of geologic time. Lava poured down the lower slopes of the volcano and almost completely covered an area of about 50 square miles. The area covered consisted of volcanic hillocks similar to the area of hillocks and flats in the center of the valley. The tops of the older hillocks can be seen protruding above the flows. From a distance, the flow appears to have a gentle westward slope and looks much like a large alluvial fan; but, when viewed close up, the surface is seen to be broken by jagged outcrops of highly fractured basalt. These outcrops were formed by schollendomes (oval mounds formed by hydrostatic pressure of liquid lava under the congealed crust), pressure ridges along the margins of the flow, and by depressions formed by the collapse of lava tubes. This area extends from the southeast edge of the valley near the juncture of U. S. Highway 97 and 99 cutoff, northwestward to the Shasta River at a point opposite Grenada.

(4) The gently rolling terrain of the north portion of Shasta Valley consists of older, coalescing alluvial fans that are partially dissected, forming a broad apron, or belt, that covers most of the valley north and west of Montague. The surface is often strewn with volcanic boulders. Between Gregory Mountain and Montague and the outlet of the valley the older alluvium stands as an eroded terrace above the entrenched meanders and the narrow flood plain of Shasta River.

Shasta River: The Shasta River is the main stream draining the basin. It enters the valley at the south end near Edgewood and meanders

northward, twisting its way around the hillocks along the trough of the valley. From Big Springs northward the river is a rather sluggish stream, having developed a narrow flood plain along most of its course through the valley. As the river leaves the valley, about five miles northwest of Montague, it becomes a vigorous downcutting stream with old meanders superimposed into a deep, narrow canyon through which it plunges to join the Klamath River to the north.

Klamath Mountains: The western part of the Shasta Valley drainage basin includes a portion of the eastern slopes of the Klamath Mountains. Mount Eddy, which attains an altitude of 9,038 feet, marks the southern end of the drainage basin. The peaks and ridges to the north are relatively low and rugged, with steep, heavy brush covered slopes. The land forms are mostly erosional in nature with mountains deeply trenched by stream action. The courses of many of the streams are controlled by the underlying rock types and by weak zones produced by differential weathering and brecciation along old faults. The Klamath Mountains form the western side of the bowl of the drainage basin as far north as the massive hills, called Paradise Craggy, at the north end of the valley.

Cascade Range: The eastern side of the drainage basin is formed by the western slopes of a chain of old volcanoes forming a part of the Cascade Range or high Cascades. Mount Shasta, the highest volcano in the chain rises almost two miles above the valley floor at the south end of Shasta Valley. This mountain, one of the most picturesque and spectacular volcanoes in the entire range, is an example of a composite volcano whose steep sides were built up by explosive ejection and effusions of relatively

viscous lava. The rest of the chain bordering Shasta Valley is made up chiefly of shield volcanoes, built by quiet effusions of fluid lava which produced relatively broad, gentle slopes. The slopes of these volcanoes are mostly constructional with relatively little modification due to erosion. Mount Shasta has been modified some by glaciation, leaving morainal ridges and hummocks, particularly near its base in the vicinity of Weed and Dwinnell Reservoir.

Near the base of the range, along the northeastern margin of the valley, a deeply eroded, pre-existing volcanic terrain called the Western Cascades, is exposed. Land forms are erosional in nature and are also controlled by some recent block faulting. The fresh fault scarps provide evidence that strains accumulating in the earth's crust have been relieved by movements in the recent geologic past, and that some of the faults are still active. Displacements of the crust along these active faults may cause earthquakes at any time. This hazard should be given adequate consideration during the design of hydraulic structures.

Rock Types and Their Development

Representative samples of all major divisions of rock types occur in Shasta Valley and its vicinity. Each type of rock, or the sediment derived from the rock, has different properties which exhibit themselves in different ways with respect to foundations, construction materials, and water-bearing capacity.

The oldest rocks in the Shasta Valley area were originally deposited as sediments in an ancient sea that covered the region during the Paleozoic ero. This era lasted about 350 million years and ended about

200 million years ago. Near the close of the Paleozoic era and during the early part of the Mesozoic era, volcanic rocks intruded these marine sedimentary rocks and also erupted onto the floor of the sea. During the middle of the Mesozoic era, the great accumulation of sedimentary and volcanic rocks were subjected to a period of extreme crustal disturbance. They were strongly folded, faulted, and uplifted. The extreme pressures and temperatures generated by this diastrophic activity metamorphosed the sedimentary and igneous rocks. The sedimentary rocks were recrystallized to form mica schist, quartzite, phyllite, metachert, and marble. The volcanic rocks were changed to greenstone and green schist. The greenstone forms the present mass of Paradise Craggy at the northern end of Shasta Valley and is exposed in the gorge of Shasta River where it makes its final plunge to the Klamath River. Other outcrops of metamorphic rocks may be seen in the ridges on the western rim of the valley.

The metamorphic rocks were intruded, during late Jurassic time, first by ultrabasic and basic igneous rocks which have since become partially altered to serpentine, and then by granitic rocks. Many of the contacts between the metamorphic and intrusive rocks are marked by faults. The faulting and serpentinization have left the rocks in a greatly weakened condition. Weak zones of faulted serpentine are exhibited along the channel of Shasta River at the north end of the valley.

After the period of uplift, during which the ancestral Klamath Mountains emerged from the sea, there followed a long interval of erosion. Gravels, sand, and muds were deposited in and along the shore of a sea, or seaway, which extended through the area during Upper Cretaceous time.

These sediments were cemented by calcite and limonite forming conglomerate, sandstone, mudstone, and shale. Several fossil horizons occur, containing numerous species of marine bivalve and gastropod forms and a large variety of cephalopods. These rocks are now referred to as the Hornbrook formation. Outcrops of these rocks are exposed at the north end and the southeast corner of Shasta Valley. Even though the formation is exposed in only a limited area, it apparently underlies most of the valley and may extend eastward beneath the Cascade Range as well.

Following the deposition of the Hornbrook sediments, the earth's crust again shifted and the area was subjected to another interval of erosion. During the early part of the Tertiary period, which began about 60 million years ago, the region became a center of volcanic activity. Andesitic and basaltic lavas spread over the landscape, forming the Western Cascades. Tuffs and tuff breccias, explosively erupted from volcanoes, blanketed the area. Torrential rains picked up the tuffs and breccias and caused extensive volcanic mudflows. Rhyolitic and andesitic domes protruded through the crust. Outcrops of these rocks, which are referred to as the Western Cascade series, are now scattered throughout Shasta Valley as clusters of cone and dome-shaped hills. North of Shasta Valley the lavas and volcanic sediments on the Western Cascade series are over two miles thick, but beneath Shasta Valley the thickness apparently is much less.

Most of the hillocks in the center of the valley are composed of andesitic lavas. These lavas contain highly fractured and vesicular zones which result in a high permeability which enables the rocks to transmit large quantities of water. This condition, if not properly treated, presents a leakage problem for dams and canals constructed on these rocks.

Highly permeable zones in the Western Cascade lavas locally serve as important aquifers for irrigation wells tapping these rocks. A buried gorge over one hundred feet deep has been detected beneath the Shasta River. This hidden gorge provides mute evidence of the period of stream erosion in the valley which followed the pouring out of the Western Cascade lavas.

At the beginning of the interval of geologic time called the Pliocene, the Western Cascades were involved in a mountain building upheaval. This upheaval opened fissures along the crest of the range from which quiet effusions of lava erupted to start building the giant cones of the Cascade Range or high Cascades. These volcanoes continued to erupt through the Pleistocene epoch and into the Recent. Mount Shasta is composed of andesitic and dacitic lavas as well as basalt. A section cut through this volcano would show layers of lava flows which had poured down the slopes of the growing cone alternating with layers of rock debris which were blasted from its craters during spectacular explosive eruptions. The volcanoes north of Mount Shasta are composed almost entirely of basaltic lavas. The volcanic rocks of the high Cascades serve as a high intake area and storage reservoir for ground water, much of which finds its way into Shasta Valley. Most of the mountainous area of the Cascades is mantled with thin, rocky soils that are underlain by highly fractured lavas, that can absorb large quantities of water from rain and snow. This is discussed more fully in the work of Seymour Mack, listed in the bibliography.

During the Pleistocene (or ice age), glaciers descended the northwestern slopes of Mount Shasta and spread into Shasta Valley as far north as the present Dwinnell Reservoir. Morainal and fluvioglacial (or outwash deposits) were formed as the result of the glaciation. The moraines and

the fluvioglacial deposits, shown as separate units on the geologic map, cover an area of about 35 square miles in the southeastern part of Shasta Valley. Except for scattered lenses of well-bedded sand and gravel in the vicinity of Dwinnell Reservoir, the morainal and fluvioglacial units consist of coarse, poorly sorted, boulderly deposits containing abundant sand, silt, clay and rock flour. Alluvial fans, composed of sandy and gravelly outwash, are still accumulating debris provided by the existing glaciers on Mount Shasta. Hydrologic data from the few wells that tap the glacial sediments suggest that the deposits have a wide range in permeability within relatively short distance.

Volcanism in the Cascades continued into the Recent epoch, which began about 10,000 years ago. Mount Shasta last erupted in 1786 when it was reportedly observed by men aboard a Spanish ship. The largest flow of any age in the area, the Pluto's Cave basalt, apparently issued from fissures on the northwestern slopes of Mount Shasta and spread over the southeasterly quarter of the valley little more than 1,000 years ago. This flow, composed of black olivine-rich, augite basalt, was not formed as a single flood of lava, but as a series of tongues of fluid lava which spurted ahead of the advancing flow, congealed, crusted over, and were buried by later tongues. This process was repeated many times, and what is to all intents and purposes a single body of lava is actually composed of a series of flow units. Highly vesicular and clinkery basalt occurs at the tops and bottoms of the individual flow layers, or units. Contraction joints have broken the flow in an extensive fracture system. Large tubes or caverns were locally formed by the drainage of the fluid lava from the insides of partially congealed flow units. A few of these lava caverns have

not collapsed but remain accessible even today. Ground water is transmitted along the vesicular contacts between flow layers, through joints and fractures within the flow, and through open and collapsed lava tubes where these occur below the water table. These factors combine to make the Pluto's Cave basalt highly permeable and very productive of ground water, hence the most important water-bearing formation in Shasta Valley.

When the high Cascades began building in early Pliocene time, the area now occupied by Shasta Valley was still a portion of the then deeply dissected western Cascades. Uplift on all sides of Shasta Valley created a basin of deposition in these dissected volcanics. The deep narrow canyons of the old landscape were filled with alluvium, while the tops of the hills were rounded and subdued by weathering and erosion. During the Pleistocene epoch the old alluvial fans that are now exposed at the north end of the valley were deposited. These fans consist mostly of poorly sorted gravel, sand, and clay mixtures with a high percentage of fines that impedes the movement of ground water. Wells tapping these deposits generally have low yields, usually large enough for domestic and stock-watering purposes only. The soils developed on the older alluvium often contain boulders; hardpan and claypan usually occur within a few inches or feet below the surface. These soil conditions often provide relatively poor agricultural land.

The Recent alluvium consists of young alluvial fan, stream channel, and plain deposits composed of lenticular beds of sand, gravel, and clay. The younger alluvial fans form a continuous apron along the west side of the valley. Stream channel deposits occur mostly under the stream bed of the Shasta River and some of its tributaries such as Parks, Willow and Yreka Creeks. The alluvial plain deposits, which are finer grained, poorly

drained deposits, occur as flood plains along the Shasta and Little Shasta Rivers and in the flats between the hillocks in the center of the valley. The permeability of the Recent alluvial deposits is highly variable, but they usually yield enough water to wells for domestic and stock-watering purposes. Locally they yield enough water for irrigation. Recent stream channel deposits along Yreka and Greenhorn Creeks were placer mined for gold. The dredge tailings left from these operations are potential sources of aggregate and pervious fill.

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A further, more extensive bibliography is included in the work by Seymour Mack, listed above.

APPENDIX B

PRELIMINARY REPORT ON FISH AND WILDLIFE IN RELATION TO PLANS FOR WATER DEVELOPMENT IN SHASTA VALLEY

by

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CALIFORNIA DEPARTMENT OF FISH AND GAME

July 1959

TABLE OF CONTENTS

TABLES

PHOTOGRAPHS

CHARTS

FIGURES

INTRODUCTION

The purpose of the investigation reported herein, was to evaluate the effects of proposed water developments in Shasta Valley on the fish and wildlife resources of the area; to recommend appropriate means of maintaining the resources; to recommend possible alternative mitigating or compensating features where detrimental effects are anticipated; to show enhancement possibilities; and finally to set forth the economic values of the existing resources under project conditions.

This report was prepared for the Department of Water Resources under terms of Inter-Agency Agreement 150001, between that agency and the Department of Fish and Game.

Scope

Because of the limitations of time and funds, the investigation was limited to a review of existing literature, interviews with persons intimately associated with the Shasta River and the fish and wildlife resources of the area, and a brief, but fairly thorough field survey of the Shasta River. Fortunately, the Shasta River has been under close observation by the Department of Fish and Game since 1930.

Description of the Area

Shasta Valley is located in North Central California in the geographical center of Siskiyou County. The valley is irregularly oblong in shape, extending for 25 to 30 miles along its north-south axis and for 10 to 12 miles in width, thus comprising an area of some 250 square miles. It lies at the foot of Mt. Shasta at an elevation of 2,500 to 2,600 feet.

On the east the valley is rimmed by Whaleback and Goosenest Mountains of the Cascade Range, while the Scott and Scott Bar Mountains of the Klamath Range form the western wall of the valley.

Below the 4,000-foot level the area must generally be classified as arid and is sparsely covered with vegetation. Annual and perennial grasses predominate the valley floor which is gently undulating and frequently strewn with volcanic rocks. The eastern half of the valley is punctuated by numerous hills or cones of volcanic origin which protrude above later deposits of basaltic lava from the Pluto's Cave flow which originated near the northeast base of Mount Shasta. The porous volcanic deposits give rise to a number of springs throughout the eastern half of the valley. Much of the soil in the area is alkaline and where this condition prevails halaphytic grasses and herbs predominate.

The valley and surrounding mountains are drained by the Shasta River (Figure 1), which flows along the western edge of a volcanic crust covering the northeastern part of California. The river is unique in that it drains both the volcanic area to the east and the older granitic Klamath Mountains on the west.

The river has its origin at the confluence of Dale and Eddy Creeks, which have their headwaters on the slopes of Mount Eddy. If flows northward through Shasta Valley, where it becomes a sluggish meandering stream, and then abruptly breaks through the mountain rim into the rugged steep-walled Shasta Canyon. It winds through the canyon for approximately eight miles before emptying into the Klamath River.

The principal tributaries to the Shasta River are Parks Creek, which originates in the Scott Mountains and joins the Shasta near Grenada,

and the Little Shasta River, which drains the mountains northeast of the valley. Although these streams run year round, the inflows are greatly reduced in the summer and fall months, by heavy upstream use. The terrain of the eastern half of the valley, being largely of volcanic origin, is extremely porous and no well-defined streams are present. However, springs are common throughout the area. During the summer months, most of the flow of the Shasta River is maintained by Big Springs the flow of which contributes 110 to 125 cubic feet per second.

Climate

Shasta Valley is typified by warm summers and cool winters. July, the warmest month, averages 72°F., while January, the coolest, averages 34°F. Their extremes are 101°F. and 1°F., respectively.

Precipitation averages 12 to 18 inches annually, with about eight inches of snow falling on the valley floor each year. About 80 percent of the annual precipitation occurs from October through March.

Socio-Economic Considerations

Yreka is the principal community and the county seat of Siskiyou County. It is situated along the old Oregon Stage Road at the northern end of Shasta Valley. In 1957, the population was 4,300. Within a 35-mile radius of the valley, the population is estimated to be 25,000.

Agriculture is firmly established; beef, dairy products, and forage crops are the principal commodities. Lumber and wood manufacturing are the principal industries in the area.

The present recreation use of Shasta Valley is rather limited. Lake Dwinnell, the principal attraction, is four and one-half miles long and

about two miles wide at its widest point. About 10 to 12 thousand visitor-days are spent at the lake annually by water-associated recreationists. The early season trout fishing is good to excellent. By midsummer, trout fishing diminishes and angling for pan fish picks up. Use of the lake for boating and water skiing is increasing. Most of the present recreational use of the lake is by local residents. The view of Mount Shasta from the valley is unsurpassed, but the tourist and recreation assets of the surrounding areas limit the value of Shasta Valley as a tourist attraction.

Quail, deer, and waterfowl provide good hunting for local residents, but the remoteness of the area and the large amount of private land discourage hunters from outside areas.

Hydrology of the Shasta River

Runoff in the Shasta drainage follows the typical seasonal runoff pattern of most of the State. Precipitation occurs mostly from October through March, with very little occurring during the summer months. However, Big Springs has maintained the flow of the Shasta River at about 100 cfs or more during the summer months under historical conditions. Currently, the late summer flows, near Yreka, are reduced to as low as ten cfs because of heavy irrigation use upstream.

A hydrograph (Chart 1) showing the mean monthly flow for 18 years during the period 1933-34 through 1954-55 is appended. The data are from the U. S. Geological Survey stream gaging station located in the E1/2, Section 24, Township 46 North, Range 6 East, MDB&M, on the right bank 0.5 mile upstream from the mouth and seven miles north of Yreka. Records are

Shasta River flowing through Shasta Canyon. Excellent Salmon spawning riffles. Photo by J. H. Wales, April 3, 1951.

missing for the period December 1941 through November 1944. The station records the runoff of the entire 796 square miles of the Shasta Valley drainage.

A maximum recorded instantaneous flow of 2,520 cfs occurred January 18, 1953, and the minimum of 3.4 cfs was recorded August 13, 1939. The average annual discharge for the 18 years of record is 163 cfs or 118,000 acre-feet per years. The unimpaired mean natural runoff is estimated at about 171,000 acre-feet per year for the period 1894-95 through 1953-54.

Chart 2 shows the average maximum, minimum, and mean monthly flows for the period of record.

In general, the winter flows (October-March) are on the order of 200 to 300 cfs. Except for the two low flow months of July and August, summer flows have generally exceeded 40 cfs. In eight of the 18 years of record, the average July and/or August flows have fallen below 20 cfs. They have averaged less than 30 cfs eleven times out of 18 years. In only one month has the flow averaged less than 10 cfs (August 1939). The unweighted means of all average July and August flows are 37 and 38 cfs, respectively.

Water Development in Shasta Valley

Agricultural development in Shasta Valley has resulted in heavy use of the present water supply; so heavy in fact, that the Shasta River is one of the few streams in the State where water rights have been completely adjudicated. Dwinnell Dam, constructed in 1926 by the Montague Water Conservation District, is located on the river east of the town of Gazelle and about 35 miles above the mouth of the river. Work on the dam in 1955 increased the storage capacity from 30,000 to 50,000 acre-feet.

About 120 square miles of drainage, with an estimated annual runoff of 44,000 acre-feet, lie above Dwinnell Dam. In addition, the District has water rights to 15,000 acre-feet annually from Parks Creek, which it diverts into the Shasta River for storage in Dwinnell Reservoir. This development provides a water supply to an area of about 19,700 acres.

A large pumping plant and diversion dam are maintained by the Grenada Irrigation District in the vicinity of Grenada. The district has a service area of about 1,800 acres. The Shasta River Water Users Association also pumps directly from the river to serve an area of 6,700 acres. The Big Springs Irrigation District, comprising some 3,600 acres, pumps its water supply from a small lake formed by Big Springs. Another 27,000 acres of land outside of organized water districts are irrigated by direct diversion from the Shasta River. A considerable amount of ground water is also pumped for local irrigation and livestock water supplies.

The net amount of irrigated land at the present time is estimated at 37,000 acres. About 72,000 acre-feet of water of the total consumptive use of 75,000 acre-feet are used for irrigating these lands.

According to preliminary estimates by the Department of Water Resources, the ultimate land use will include 105,000 irrigable acres which would require about 185,000 acre-feet of water annually or supplemental water amounting to 110,000 acre-feet. The ultimate needs are estimated at 197,000 acre-feet; about 122,000 acre-feet more than is presently used.

Proposed water development plans call for construction of local works to conserve the water now lost through runoff, and the importation of water from the Klamath River to supplement the local supply.

PROPOSED WATER DEVELOPMENT PROJECTS

At the present time three dam sites are being considered for water conservation purposes. They are the Grenada Ranch Dam, Montague Dam, and an alternative to Montague, Gregory Mountain Dam. Tentative dam and reservoir statistics for each are given in Table B-1.

The Department of Water Resources engineering study emphasizes the Grenada Ranch Reservoir Project. Expectations are that it would be the next major water resource development in Shasta Valley. It is therefore, assumed to be the initial project and is treated in more detail in this report than the Gregory Mountain and Montague proposals.

Grenada Ranch Dam

This is the uppermost of the three proposed dams. It would be located about 25 miles above the mouth of the Shasta River in Section 36, Township 44 North, Range 6 West, MDB&M. This site is about three miles southeast of Grenada and eleven miles southeast of Yreka. There are about 352 square miles of drainage area above the site and an estimated 85 to 90 thousand acre-feet of runoff available annually at the dam site. Most of the storage water would come from the winter flow of Big Springs and from some winter runoff. Dwinnell Reservoir, which captures most of the upstream runoff of the Shasta River and Parks Creek, rarely spills. Existing water rights would prevent any storage of the summer flow of Big Springs. It is anticipated that Grenada Ranch Reservoir would undergo heavy drawdown each year.

TABLE B-1

TENTATIVE DAM AND RESERVOIR STATISTICS

Name of dam	Grenada Ranch	Montague	Gregory Mountain
Type of dam	earthfill	earthfill	earthfill
Stream bed elevation	2,538 feet	2,407 feet	2,458 feet
Height above stream bed	52 feet	82 feet	108 feet
Gross storage capacity	22,400 a.f.	83,000 a.f.	77,500 a.f.
Normal minimum pool	5,000 a.f.	43,000 a.f.	36,000 a.f.
Normal maximum pool elevation	2,580 feet	2,498 feet	2,528 feet
Normal minimum pool elevation	2,556 feet	2,482 feet	2,518 feet
Normal seasonal fluctuation 1/	35 feet	35 feet	25 feet
Active storage	20,500 a.f.	75,000 a.f.	75,000 a.f.
Miles of shoreline at normal minimum pool	25 miles	45 miles	50 miles
Surface area at average maximum capacity	1,120 acres	2,480 acres	4,150 acres
Surface area at average normal minimum pool	450 acres	1,620 acres or less	2,250 acres

1/ Subject to correction.

Montague Dam

This, the lowermost dam, would be located about ten miles above the Shasta River mouth in Section 7, Township 45 North, Range 6 West, MDB&M, about 3.5 miles northeast of Yreka and 3.5 miles northwest of the town of Montague. About 670 square miles of drainage area, with an annual unimpaired natural runoff of 147,000 acre-feet, lies above the dam site. Water to be stored in the reservoir would come principally from winter runoff, and irrigation return water. However, in the event that Montague Dam is constructed prior to Grenada Ranch Dam, a substantial part of the water would come from the winter flow of Big Springs. As in the case of Grenada Ranch Dam, virtually all storage would occur in the winter months, because of heavy summer use. Annual withdrawals from storage would be from 20 to 50 percent of the normal storage capacity. In normal years the pool would decrease from a maximum of 2,500 to about 1,600 surface acres and in dry years as low as 850 surface acres.

Gregory Mountain Dam

The Gregory Mountain Dam site is an alternative to the Montague site. The dam would be situated in Section 33, Township 43 North, Range 6 West, MDB&M, about one mile southwest of the town of Montague and about six miles east of Yreka. The water supply would come from the same sources as Montague, except that there would be a slight reduction in the amount of drainage area above the dam site. Since this site has only recently come under consideration, detailed statistics concerning the dam and reservoir are not available. In many respects, however, it would be similar to Montague Dam and Reservoir in size and operation.

Shasta River at site of proposed Montague Reservoir. Good Salmon spawning areas in this section. Photo by J. H. Wales, April 3, 1951.

The dam would be at a stream bed elevation of 2,458 feet, with a maximum crest height of about 108 feet above stream bed elevation. Active storage would be on the order of 75,000 acre-feet.

Conveyance Features and Diversions

Plans are not sufficiently advanced to provide any details concerning diversions and conveyance features. However, canals or conduits would be necessary to transport water for municipal use in Yreka and for agricultural purposes in the various service areas. Pumps would be required at each dam location to lift the water to distributive canals.

Staging

Details are also lacking regarding the staging of a water development program in Shasta Valley; however, it is generally assumed that Grenada Ranch Dam would precede any downstream development. There would be a considerable lapse of time between construction of the two dams.

FISH AND WILDLIFE RESOURCES

Anadromous fish would be most seriously affected by water developments in Shasta Valley. King salmon (*Oncorhynchus Tshawytscha*), steelhead trout (*Salmo gairdneri*), and silver salmon (*Oncorhynchus kisutch*) are represented in this group. Resident rainbow trout (*Salmo gairdneri*) and brown trout (*Salmo trutta*) are also present throughout the drainage.

King Salmon

By far the most important species is king salmon. It is well established that under historical conditions, the Shasta River supported

large populations of both spring-run and fall-run king salmon, perhaps the largest in the entire Klamath Basin.

Historically, spring-run fish entered the Shasta River during May and June, spent the summer in the river under the ideal donditions provided by the cool, steady flow of Big Springs, and spawned with the appearance of the fall freshets and increased flows. This run has now been all but eliminated by the warm, low flows resulting from heavy upstream water use. The fall-run now sustains the fishery.

Fall-run king salmon enter the Shasta in early September when the flow reaches about 100 cfs, an amount which appears necessary to encourage their entry. They begin spawning shortly thereafter and most spawning is completed by November 15. Emergence of the salmon fry from the stream gravels is usually complete by February 1. Immediately after emergence, the fry begin their downstream journey to the ocean. The peak of the downstream migration is reached during February and continues through April.

In 1930, the former Division of Fish and Game established a counting station on the Shasta River a short distance above the mouth. In 1938 the station was relocated about six miles upstream and then again returned to the downstream location in 1957. The annual fall counts of king salmon are shown in Table B-2. The 28-year average is 22,548 fish.

The actual counts from 1938 through 1955 have been enlarged by one-third to account for that proportion of the run which spawned below the upstream counting station. This figure was established by field observations in 1937. The results are conservative in view of the fact that later observations have indicated that about two-thirds of the run frequently spawn below the counting station or more uniformly over the usable sections of the

Shasta River at Confluence with Big Springs. Excellent spawning riffles for both Salmon and Steelhead in this area. Photo by J. H. Wales, April 3, 1951.

TABLE B-2

SHASTA RIVER UPSTREAM MIGRANT KING SALMON COUNTS

Year	Salmon	Year	Salmon
1930	19,338	1944	17,421*
1931	81,884	1945	27,562*
1932	34,689	1946	11,500*
1933	11,570	1947	2,341**
1934	48,668	1948	2,037**
1935	74,537	1949	2,139**
1936	46,115	1950	2,500**
1937	33,255	1951	3,067*
1938	13,773*	1952	2,524*
1939	42,832*	1953	2,432*
1940	83,568*	1954	3,945*
1941	20,079*	1955	2,738*
1942	17,311*	1956	---
1943	15,185*	1957	2,234
		1958	6,089

AVERAGE ANNUAL - 22,548

* One-third added to runs because of upstream relocation of rocks.
** Two thousand fish added to actual counts.

river. From 1947 through 1950, 2,000 fish were added to the number counted as a result of field counts of fish below the racks.

The areas used by king salmon for spawning include the lower eight miles of river, from the mouth upstream to Montague, and about three miles of excellent gravel in the river in the vicinity of its confluence with Big Springs. Several miles of intermittent gravel and riffle areas are available both above and below Grenada. The slow meandering section of the river in the valley is generally poor or not at all usable for spawning. The stream bed from Big Springs up to Dwinnell Reservoir contains good spawning gravel, but lacks adequate flows. Thus, about one-half of the 35 miles of river between the mouth and Dwrinell Reservoir are presently used by king salmon for spawning.

Steelhead Trout

About 6,000 steelhead are estimated to utilize the Shasta River for spawning. Accurate counts are not available because by the time the bulk of the fish enter the river in January and February, the racks at the counting station are removed to eliminate flood damage. The run most likely varies between three and eight thousand fish. In 1948-49 it was not necessary to remove the racks and almost 4,000 fish were counted.

There are two runs of adult steelhead into the Shasta River, a fall-run and a winter-run. Based on this single count in 1948-49, the winter-run is larger than the fall-run. The fall-run enters the Shasta River during September through November. The winter-run enters January to April. When water temperatures are below 40°F. there is little upstream movement.

Steelhead spawn from about the first of January into April, and the fry are usually out of the gravel by the end of May. Unlike king salmon, the small steelhead remain in fresh water for a year or more before migrating to the ocean.

An unknown proportion of the adult steelhead spawn in the gorge section of the Shasta River. The section of the river below Big Springs, and the section of Big Springs between the Shasta River and the lake at the head of the springs are heavily utilized. A fair number use the gravels in the main river above its condluence with Big Springs when flows are adequate. Some fish also enter Parks Creek when satisfactory flows are present.

Silver Salmon

Spawning requirements of this species are similar to those of steelhead in many respects. The runs in the Shasta River probably average

a little over a thousand fish a year. They enter the river from October through January and spawn during the same period. Silver salmon utilize gravel areas similar to those used by steelhead. Some of the young fish remain in the river for a year before moving down to the ocean.

Resident Trout

A fairly large population of resident rainbow trout exists in the Grenada-Big Springs area under the influence of the flow from Big Springs. Brown trout are also present throughout much of the river.

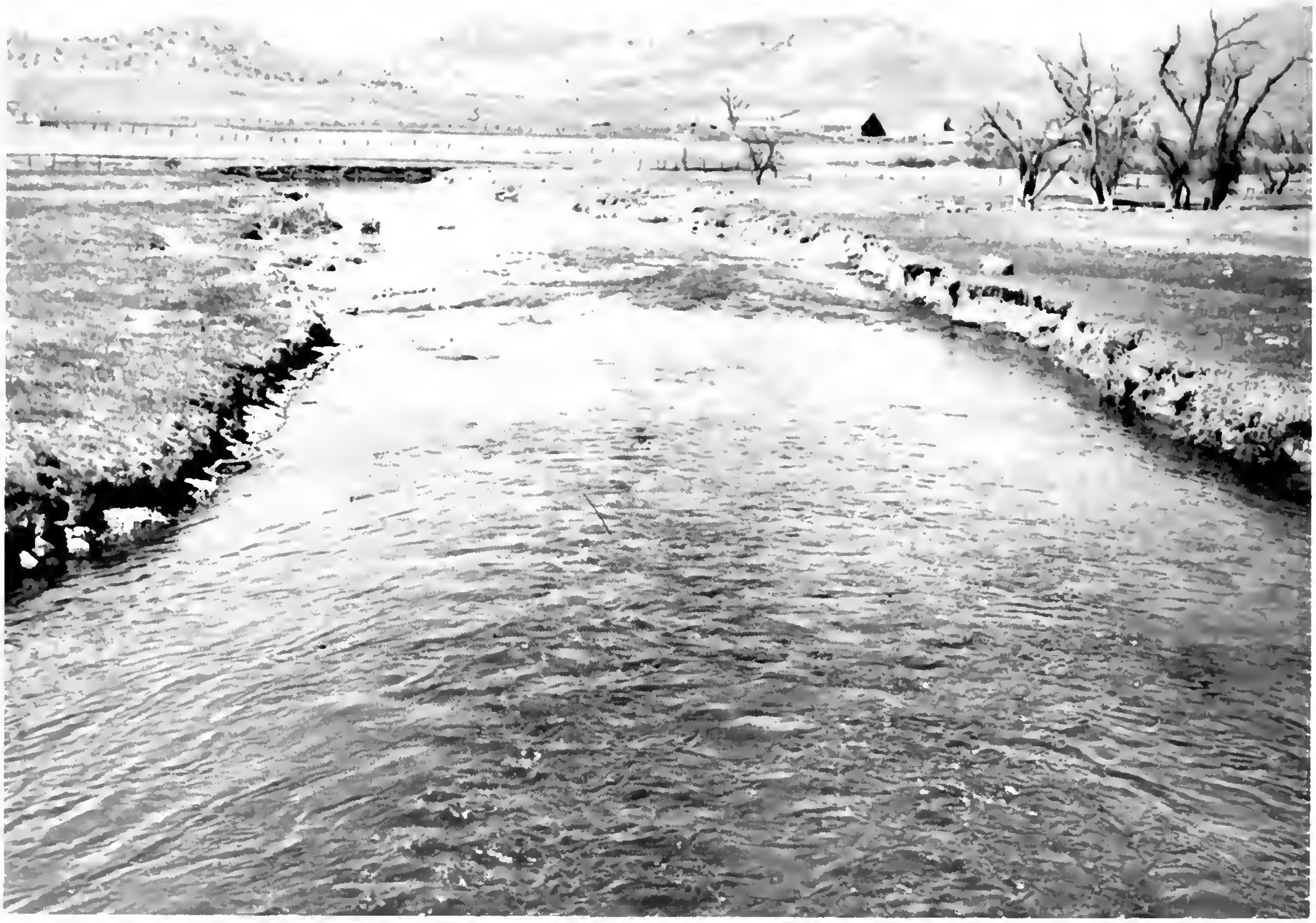
Catfish

The slower meandering sections of the river in the valley provide catfish angling primarily for the local residents.

Angling

The gorge section of the river is fished heavily during May of each year. Opening day creel censuses which have been conducted each year since 1948 show an average of about 350 anglers. From 1953 through 1956, the number of anglers increased to an estimated 500 to 600 on opening day. At this time of year there is rather phenomenal angling success for juvenile steelhead which average about seven to eight inches in length. The opening day catch varies from year to year, but in the last six years has been estimated at 3,000 to 5,000 fish for an average catch per angler of eight to thirteen fish.

The angler use diminishes from the opening day peak to negligible proportions by the end of May, at which time the young steelhead have largely moved out of the area. The total number of angler days supported by this portion of the fishery probably averages about 2,500 per year.



Shasta River upstream from Yreka Agar Bridge. Intermittent riffles for Salmon and Steelhead spawning. Favored area for Catfish angling. Photograph by J. H. Wales, April 3, 1951.

In the valley, catfish and rainbow and brown trout angling are minor sport fisheries about which little is known. A total of 1,000 angler days per year appears to be a reasonable estimate for use between the gorge and Dwinnell Dam.

The total number of angler days is, therefore, estimated to be on the order of 3,500 days per year. In addition to this angling, salmon and steelhead originating in the Shasta River contribute a great deal to angling both in the ocean and in the Klamath River below the mouth of the Shasta River.

EFFECTS ON FISH AND WILDLIFE

Potential Reservoir Fisheries

Each of the proposed reservoirs has rather limited possibilities for establishing and developing fisheries. Grenada Ranch Reservoir would fluctuate too much to establish a permanent sport fishery. Montague and Gregory Mountain are also limited in this respect, but both would possess greater potential than Grenada Ranch.

Even though fish populations may be established, the angling potential is limited if experience at Lake Dwinnell can be used as a measure. Other lakes closer to population centers tend to take the play from areas as remote as Shasta Valley.

If fisheries management plans include the planting of catchable trout in the reservoirs, angler use could be expected to increase. This would be especially true as the population increases. Whether the increased use would justify planting catchable trout is not known.

Trout Fishing in the Shasta River Canyon. Good Salmon spawning riffle. Photograph by Millard Coots, California Department of Fish and Game, April 28, 1956.

Wildlife

Detailed studies have not been made of the probable effects of the proposed dams and reservoirs on wildlife other than fish. However, the benefits apparently far outweigh the detriments. Muskrat and beaver are the principal species that would be adversely affected and they are not too numerous. Somewhat less than two thousand muskrats are taken along the Shasta River each year by trappers. Pelts are generally worth about one dollar each.

The proposed reservoirs should serve as excellent wintering and resting areas for waterfowl and produce excellent hunting. Agricultural practices as a result of project water would probably be conducive to an increase in the pheasant population, which would result in increased hunting of these game birds.

FISHERIES MAINTENANCE

Generally speaking, king salmon spawn most heavily in the lower reaches of the Shasta River. Any of the proposed dams would eliminate about forty percent of the steelhead and silver salmon spawning and nursery areas. The amount of king salmon spawning area eliminated would vary with the proposals.

Grenada Ranch Dam would inundate and prevent access to spawning gravels used by 25 percent of the king salmon.

Gregory Mountain Dam would effectively remove spawning areas used by about 35 percent of the king salmon. Montague Dam would eliminate practically all of the spawning areas available in the Shasta Valley or about 45 percent of the total Shasta River spawning grounds.

Fortunately, Shasta River salmon and steelhead populations have been under observation for many years and information is available upon which to base a fisheries maintenance plan. Maximum flows to maintain fisheries would be required during the fall at the height of the salmon spawning season. Flows could then be diminished to a level which would keep the incubating eggs well covered and still provide satisfactory spawning conditions for the remaining 60 percent of the steelhead trout and silver salmon (Chart 2).

In addition to maintenance flows, provisions for artificial propagation facilities would be needed to replace lost spawning and nursery areas above the dam sites. The most apparent solution at this time appears to be hatchery facilities of sufficient size to replace the proportion of fish lost. Artificial spawning channels might be used to replace part of the run. However, at this time, not enough is known about them to determine whether they would be feasible.

Water temperatures are particularly important from the time the adult fish enter the river until spawning is completed. The fish are either ripe or are developing eggs and sperm at this time. Temperatures above 56°F. decrease the viability of the eggs and cause excessive mortality to developing embryos.

Every effort should be made to insure satisfactory water temperatures. Multiple outlet works should be provided at any of the proposed dams to supply the coolest water possible during the spawning period. Under enhancement flow schedules, 56°F. water would be desirable by September 1.

If further consideration is given to the development of this project, a detailed study of probable temperatures will be needed. Final

determination of a satisfactory fisheries program will rest upon the availability of sufficient quantities of water within the proper temperature range.

The Shasta River king salmon count has averaged about 22,500 fish per year, for the 28 years of record between 1930 and 1958, as Table B-2 shows. However, the average is misleading in this case in that commencing with 1947 an unprecendented reduction in the runs occurred. Between 1947 and 1957 less than 3,000 king salmon per year were counted. In 1958 6,000 were counted.

There is no satisfactory explanation at this time for the decline. There was a reduction in most king salmon runs of the State during the same general period, but none as severe as this. While part of the reduction may be attributed to natural phenomena, it seems likely that some other factor or combination of factors has affected the runs in the Shasta River. Such things as unfavorable water quality or inadequate flows can seriously impair the upstream migration of these fish.

The fact that the 1958 king salmon run trebled those of the preceding 10 years and that steelhead in the past few years have been holding their own and perhaps even increasing is justification for optimism on the future of the Shasta River fishery. Judging from the hydrology, there has been no great change in flow conditions. Therefore, there is reason to believe that the current low counts are not representative and that the salmon runs may again increase toward their former status, barring future adverse water development. On the other hand, the low runs of the 1947-57 period must be recognized. It therefore appears proper, in determining what shall constitute an average king salmon run in the Shasta River, to make an appropriate adjustment rather than using the arithmetic average.

The median count of 15,000 fish appears to be an equitable solution, in this case, since both of the above considerations are represented. It will therefore be used in this report as a basis for further discussion on the maintenance and enhancement aspects of the proposed water developments.

Fisheries maintenance plans involve a combination of flow release schedules and artificial propagation facilities. The flow schedules are based upon the seasonal requirements of the fish for spawning and incubating purposes and the minimum amount of water necessary to keep resident fish, juvenile steelhead, and silver salmon in good condition.

These flow schedules are predicated on flows as measured immediately above the confluence of Yreka Creek.

Hatchery facilities would be required to replace 40 percent of the steelhead and silver salmon regardless of which proposed dam is built. Good hatchery sites are difficult to find in the Klamath Basin. Big Springs is a potential site, but would need detailed investigations as to suitability of the water supply. About 30 cfs would be required to carry on normal fish cultural operations. The use, however, is nonconsumptive and the water could be returned for project use or as partial fulfillment of stream flow maintenance requirements. The maintenance schedules would provide adequate flows to attract fish to the trapping facilities.

Maintenance Plan 1

No matter which dam is built, the same maintenance flows would be required to maintain the fishery. On the other hand, the farther upstream the dams are located, the smaller the artificial propagation facilities

that would be required. There would also be the additional advantage of preserving more of the natural spawning areas.

Plan 1 provides a balance between flow releases and hatchery facilities. It is the most desirable of the proposed maintenance plans. The flow release pattern is listed in Table B-3 and is shown on Chart 2.

Commencing September 15, flows of 100 cfs would be provided to allow king salmon to enter the river and proceed to the spawning areas. This flow would be maintained until the height of the spawning season. It would then be increased to 200 cfs to provide the maximum spawning area. Such an increase in the flow should encourage the fish to use areas unavailable at the 100 cfs flow and reduce disturbance of earlier nests.

TABLE B-3

MAINTENANCE PLAN 1,
FISHERY FLOW RELEASE SCHEDULE

Dates	Cubic feet per second	Annual acre-feet
September 15 to October 14	100	
October 15 to November 14	200	
November 15 to February 28	150	
March 1 to May 31	50	
June 1 to September 14	30	---
TOTAL	---	66,000

The flow could be reduced to 150 cfs on November 16 after the bulk of the king salmon have spawned. This flow would be adequate to incubate eggs already deposited and provide for the downstream migration of the

fry. It would provide a reasonable spawning area for the remaining silver salmon and steelhead expected to use the section of the river below the proposed dam. Between March 1 and June 1, flows of 50 cfs would support the resident fish and early season Angling. While reduction of flows to 30 cfs might not be satisfactory for angling, it should be enough to keep the resident fish and the juvenile steelhead and silver salmon alive.

Fisheries maintenance flow recommendations ordinarily provide for reduced flows during years of abnormally low runoff. During these years the fisheries would suffer even with unimpaired conditions. The greatest difficulty in proposing a "dry year clause" is determining conditions that would actually result in a dry year. The following dry year clause, based on reservoir storage levels, is proposed for Grenada Ranch Reservoir assuming a storage capacity of 22,400 acre-feet.

The reduction of storage below 4,600 acre-feet at any time during September would result in setting fisheries releases at the level of Schedule 2 (Table 5), on September 15, provided that no more than 21,200 acre-feet of project water had been used for irrigation, industrial, and domestic purposes during the previous water year. Should storage reach 7,500 acre-feet on or before November 30, releases would be increased immediately to Schedule 1. However, failure to reach 10,000 acre-feet of storage by December 31, would result in continuation of or reduction to Schedule 2. Reservoir storage below 13,500 acre-feet on January 31, would result in further reductions of maintenance releases to 70 percent of Schedule 2. If the reservoir has not filled on or before April 1, fisheries releases would be reduced on April 1 to the natural inflow to the reservoir after prior rights had been met, provided that agricultural use would be

reduced proportionately. The natural flow would be maintained until the reservoir filled or until September 14, inclusive.

Studies have not been made to determine how often dry years, as defined by this clause, would occur. It may be necessary to modify the dry year provisions pending the results of such studies. It should not be necessary to invoke a dry-year clause more often than 20 percent of the years. If dry years occurred more often than this it probably would be necessary to modify the clause.

Similar dry-year provisions could be developed for Montague and Gregory Mountain Resrvoirs based on appropriate critical storage levels.

Hatchery facilities would be required to replace lost spawning areas. The size of the hatchery facilities would depend upon which of the proposed dams were built.

TABLE B-4

HATCHERY EGG CAPACITY 1/
MAINTENANCE PLAN 1

Species	Grenada	Montague	Gregory Mountain
Steelhead	240,000	240,000	240,000
Silver Salmon	50,000	50,000	50,000
King Salmon	5,250,000	9,450,000	7,350,000
TOTAL	5,540,000	9,740,000	7,640,000

1/ Rounded to nearest 10,000.

Hatchery egg capacities in Table B-4 are based on an annual run of 6,000 steelhead and 1,000 silver salmon with a survival of 50 percent from egg to yearling stage. A return of 2 percent of stocked fish as adults would be expected.

King salmon egg capacities are based on an annual run of 15,000 less the percentage spawning in the stream below the dam.

The capital cost of an adequate installation would be on the order of $475,000 excluding the site and road construction costs. The cost of adult trapping facilities is not included. Depending on the location of the hatchery, this might vary from $25,000 to $150,000. Annual operation and maintenance costs would be about $50,000.

Maintenance Plan 1A

Plan 1A is based upon the same fisheries maintenance flows proposed for Plan 1 and combination of the required hatchery facilities with Mt. Shasta State Fish Hatchery. A small spring, which has a flow of about 10 cfs is located near the hatchery. Hatching and rearing facilities could be built here and operated as a part of the Mt. Shasta Hatchery.

In contrast to the unknown quality of the water to be released from the project reservoirs, the spring water is believed to be well suited for fish cultural purposes. For Plan 1A to become a workable plan the purchase of the spring would have to be assured. The existing hatchery water supply is fully exploited.

The trapping and spawning facilities would be built at the base of the dam. The adult fish would be held in suitable ponds or tanks to ripen and spawning operations would be conducted there.

The total cost of the facilities, including trapping and holding facilities and a cabin at the dam, two residences, incubator trays, troughs, hatchery building, and ponds at the spring is estimated to be about $250,000. The cost of the spring and land is not included. No major equipment is included because it is believed that Mt. Shasta Hatchery equipment could be used.

Combining the facilities with those of the existing hatchery would be expected to increase the efficiency of the operation. Fish planting costs would be higher than with the hatchery at the base of the dam. However, the increase in these costs would be negligible. It is believed that the fish could be reared at a cost of about $1 per pound. Since it would be necessary to rear about 23,000 pounds of fish to maintain the runs with Grenada Ranch Reservoir, annual operating costs would be expected to be about $23,000.

The cost of facilities and the annual operating costs would be proportionately higher with Montague or Gregory Mountain Reservoirs.

Maintenance Plan 2

In this plan, artificial propagation would be relied upon to maintain the anadromous fish runs. The water release schedule, shown in Table B-5, would provide only enough water to enable anadromous fish to enter the river, provide for the migration to trapping facilities, and limited downstream spawning. A reduction of at least 50 percent would be expected to occur in the population downstream from the lowermost dam.

TABLE B-5

MAINTENANCE PLAN 2, FISHERY FLOW RELEASE SCHEDULE

Dates	Cubic feet per second	Annual acre-feet
September 15 to November 14	100	
November 15 to February 28	75	
March 1 to May 31	50	
June 1 to September 14	30	---
TOTAL	---	43,000

The same type dry-year fisheries flow release schedule proposed for Grenada Ranch Reservoir Maintenance Plan 1 would be suitable for Maintenance Plan 2. It is suggested however, it would provide only for reduction of fisheries maintenance flows to 70 percent of Schedule 2 provided reservoir storage was below 13,500 acre-feet on January 31. If the reservoir was not full by April 1, fisheries releases would be reduced to the natural inflow to the reservoir after prior rights had been met, provided that agricultural use would be reduced proportionately.

Table B-6 lists the size of the hatchery facilities required under Plan 2. Basing cost of the facilities on the criteria of Plan 1, the cost would be about $650,000 and annual operational costs would amount to about $75,000 for Grenada Ranch Reservoir. It would be slightly higher with Montague or Gregory Mountain Reservoirs.

TABLE B-6

HATCHERY EGG CAPACITY 1/
MAINTENANCE PLAN 2

Species	Grenada	Montague	Gregory Mountain
Steelhead	420,000	420,000	420,000
Silver salmon	70,000	70,000	70,000
King salmon	13,125,000	15,225,000	14,175,000
TOTAL	13,615,000	15,715,000	14,665,000

1/ Rounded to nearest 5,000.

This is not a desirable plan since artificial propagation would be necessary to replace the bulk of the anadromous fish run. The highly successful early season fishery for yearling steelhead and silver salmon

would be sacrificed or at best be supported by hatchery stocking requiring additional facilities. The plan should be adopted only as a last resort.

Maintenance Plan 2A

Fisheries maintenance flows would be the same as in Plan 2. Artificial rearing facilities would be combined with Mt. Shasta State Fish Hatchery as in Plan 1A.

The cost of hatchery facilities, exclusive of land acquisition, would be about $350,000. Operating expenses would be about $50,000 annually. These costs are based on the construction of Grenada Ranch Reservoir. Construction of Montague or Gregory Mountain Reservoirs would increase the cost proportionately.

FISHERY ENHANCEMENT

The annual king salmon counts from 1930 through 1946 (Table B-2) best illustrate the size of the king salmon runs which would be expected under favorable conditions. The average annual count over the 17-year period is 35,250, with a peak count of more than 80,000 adult king salmon. The 35,250 average is based upon flows originating at Big Springs since this was the farthest upstream point ordinarily available to the fish during the 29-year period. With few exceptions, flows between Big Springs and Dwinnell Dam have been inadequate to contribute to the spawning area.

During the past ten years, the runs have been far under the potential of the river. Any increase in the number of returning adults above the 15,000 maintenance average should be considered enhancement.

It should be emphasized at this point that the salmon which return to the river to spawn are only part of the total population. Studies have shown that approximately three times the number counted are taken by sport and commercial fishermen. Actually, it is the fish which are caught that are of monetary value; the fish which enter the rivers and spawn, die shortly afterward; they thus serve to maintain the population. Steelhead, however, may spawn more than once.

At this time it appears that the greatest fisheries benefit would come with stream flow releases of between 96,000 and 117,000 acre-feet annually. Benefits should be somewhat proportional to the increase in flows until the point of diminishing returns is reached at 117,000 acre-feet. Benefits at 117,000 acre-feet annually should be about 20 percent greater than at 96,000. Table B-7 lists the flow schedule in cubic feet per second for the two proposed flows.

These flows would provide ample water during all seasons of the year. Schedule No. 2 provides for increased flows during the spawning and migration time. More area would be available for spawning.

Obviously the farther upstream these flows are initiated the greater the benefit will be, because of the additional amount of spawning gravel and stream nursery area available. Therefore, enhancement plans were based on location of the dams as well as the proposed flow releases and assuming satisfactory temperatures. Artificial propagation facilities are not considered in the plans although spawning channels might increase production and should be considered in final planning.

Grenada Ranch Enhancement Plan

This plan would envision the construction and operation of Grenada Ranch Dam primarily as a fisheries enhancement project. Table B-8 shows the number of king salmon expected under this plan.

TABLE B-7

ENHANCEMENT FLOW SCHEDULE
IN CUBIC FEET PER SECOND

Dates	Schedule No. 1	Schedule No. 2
June 1 to August 31	100	100
September 1 to September 30	100	200
October 1 to November 30	250	300
December 1 to January 31	150	200
February 1 to February 28	150	150
March 1 to March 31	100	150
April 1 to April 30	100	100
May 1 to May 31	50	50
ANNUAL TOTAL IN ACRE-FEET	96,000	117,000

TABLE B-8

NUMBER OF KING SALMON EXPECTED WITH
ENHANCEMENT FLOWS IN THE SHASTA RIVER1/

Grenada Ranch Plan

	Schedule No. 1	Schedule No. 2
Average annual run in river	26,500	31,800
Number caught sport and commercially	79,500	95,400
TOTAL	106,000	127,200

1/ Based on 35,250 annual average of 1930-46 period. The average annual run would be less than the 1930-46 period because of reduced spawning area available.

No enhancement is expected for steelhead and silver salmon because of the 40 percent reduction in their spawning area. However, the increased summer flows would result in better survival to yearling size of the ones actually spawned. In time, increasing numbers of these fish could be expected to utilize the lower reaches of the river. The increase would not entirely compensate for the lost spawning grounds.

The resident fishery below the dam would be benefited. The fishery in the reservoir would probably equal the amount of fish presently occurring in that section of the river. Consistent flows would provide for better survival and reproduction in the river below the dam.

Gregory Mountain Enhancement Plan

This plan would provide enhancement flows from Gregory Mountain Dam. Benefits would be considerably less than could be expected from Grenada Ranch because of the elimination of important spawning areas between the two sites.

The resident fishery below the dam would be expected to improve, although there would be less area to support this fishery than with Grenada Dam.

The fishery in Gregory Mountain Reservoir would be better than in Grenada Ranch. The reservoir fishery would compensate for the reduction in the area below the dam as far as the resident fishery is concerned.

Table B-9 lists the number of king salmon expected under Plan 2.

TABLE B-9

NUMBER OF KING SALMON EXPECTED WITH ENHANCEMENT FLOWS IN THE SHASTA RIVER 1/

Gregory Mountain Plan

	Schedule No. 1	Schedule No. 2
Average annual run in river	23,000	27,600
Number caught sport and commercially	69,000	82,000
TOTAL	92,000	109,600

1/ Based on 35,250 annual average of 1930-46 period.

ECONOMIC CONSIDERATIONS

The statistics presented earlier are presented in Table B-10 for the purpose of evaluating the Shasta River fisheries resources with and without the proposed projects.

Wildlife values are not sufficiently known at this time to be discussed in this report.

The annual number of angler days is estimated at 3,500. This angling is principally for juvenile steelhead, silver salmon, and resident fishes.

TABLE B-10

NUMBERS ANADROMOUS FISH ORIGINATING IN THE SHASTA RIVER

	King salmon	Steelhead	Silver salmon
Present median annual run	15,000	---	---
Present average annual run	---	6,000	1,000
Average number exploited	45,000	4,000	3,000
TOTAL	60,000	10,000	4,000
Escapement Ratio	1:3	3:2	1:3

Fisheries Values Without the Project

Using values recently estimated by the Department of Fish and Game for Sacramento-San Joaquin River salmon, an estimate of the annual value of the salmon resource of the Shasta Valley can be obtained. It has been established that each Sacramento River salmon was worth $6.50 at the wholesale level or about $0.30 per pound. The total number of fish was multiplied by $6.50.

A similar process for Klamath or Shasta River fish would yield a per-fish value of about $3.60 since these fish weigh about twelve pounds each on the average. The total annual value by this process would be on the order of $216,000.

Silver salmon average about six pounds each. At thirty cents a pound, each fish would be worth $1.80. The annual value would be about $7,000.

Steelhead cannot be taken commercially in California, but the value per fish as a sport fish is assumed to be at least as great as that of king salmon of the Sacramento River. For a total of 10,000 fish, the annual value would be on the order of $65,000. The ratio of escapement to catch for steelhead is estimated at 3:2 rather than 1:3.

Using the value of $14.00 per day (Outdoor California, April 1957) an annual value of $49,000 is assigned to angling in the Shasta River itself. These values are shown in Table B-11.

In the preceding discussion the overhead costs of the commercial fisherman is not deducted from the wholesale value of the fish.

TABLE B-11

ECONOMIC VALUES OF SHASTA RIVER FISHERY RESOURCES

Without the Projects

	Annual value
King salmon	$216,000
Silver salmon	7,000
Steelhead trout	65,000
Angling	49,000
TOTAL	$337,000

Fisheries Values With the Project

The fisheries value with the project should equal the present value under Maintenance Plan 1. If the flow schedules and artificial facilities recommended are not provided, there would be detrimental effects to the fisheries and a reduction in values roughly in proportion to the omission. Artificial production costs would reduce the annual net value by the cost of production.

Maintenance Plan 2 would sacrifice the early season angling for yearling steelhead, trout, and silver salmon amounting to a reduction in value of about $35,000. In addition, artificial propagation costs would be increased sharply.

The approach used in determining economic benefits attributable to enhancement is identical to that used previously, that is, in terms of annual values. Table B-12 shows the estimated value of stream flows

totaling 96,000 acre-feet per annum as suggested in Schedule No. 1, Table B-7. The values shown include all considerations previously discussed, such as the origin of the flows and the escapement and exploited portions of the fish population.

TABLE B-12

ESTIMATED VALUE OF THE SHASTA RIVER
FISHERIES WITH ENHANCEMENT PROPOSALS

Project	Annual values in dollars		
	Anadromous fish	Resident fish	Total
Grenada Ranch	389,000	49,000	438,000
Gregory Mountain	338,000	49,000	387,000

Table B-13 shows the estimated increase in the annual value of the Shasta River fishery based on enhancement flows of 96,000 acre-feet.

TABLE B-13

COMPARISON OF ANNUAL ENHANCEMENT VALUES
IN DOLLARS WITH VALUES WITHOUT THE PROJECTS 1/

Project	Value without project	Increased value with enhancement	Enhancement value 2/
Grenada Ranch	337,000	438,000	101,000
Gregory Mountain	337,000	387,000	50,000

1/ Based on median annual run of 15,000 king salmon without projects and on the average annual run of 35,250 with unimpaired flows at Big Springs.

2/ Based on enhancement flow of 96,000 acre-feet annually.

Of the three proposed reservoirs on the Shasta River, Grenada Ranch has the most promise as fisheries enhancement project. It would eliminate the least spawning area, since it is the uppermost of the three proposals. If operated with enhancement flows of 96,000 acre-feet annually, it would provide an increase of about 29 percent in the annual average value of the fishery. However, peak runs well in excess of the annual average could be expected.

Gregory Mountain would provide a 15 percent increase over present values with enhancement flows. This is only a little more than one-half as much as Grenada Ranch, due to the reduction in spawning area.

The construction of Montague Dam would eliminate even more spawning area. The proposed enhancement flow would not increase present values. Since the enhancement flows would require nearly all the water yield of the Shasta River, nothing would be gained by constructing this project for fisheries enhancement.

SUMMARY

An investigation was conducted to evaluate the effects of the proposed water development plan for Shasta River on fish and wildlife. The construction of the porposed dams as fisheries enhancement projects was also evaluated. The investigation was limited to a review of existing literature and previous field observations.

Three proposed dams are being considered for construction on the Shasta River. Water stored by these dams would be used to supply irrigation and domestic needs of Shasta Valley. No power features are included in the proposed development.

Grenada Ranch Dam, the uppermost of the dams, would cut off about 25 percent of the remaining king salmon spawning area and 40 percent of the silver salmon and steelhead spawning areas.

Montague Dam, the lowermost of the three, would cut off 45 percent of the king salmon spawning area as well as 40 percent of the steelhead and silver salmon spawning grounds.

Gregory Mountain Dam is proposed as an alternative to Montague Dam and is located a few miles above it. About 35 percent of the king salmon spawning area, in addition to 40 percent of the steelhead and silver salmon spawning area, would be lost.

Although intensive water use has changed conditions in the Shasta River, it is still one of the most important salmon spawning tributaries in the Klamath River.

The average annual number of king salmon entering the river on their spawning migration over the 29-year period from 1930 through 1958 is 22,500. The highest number was 83,568 in 1931, and the lowest number was 2,037 in 1948. The steelhead trout run varies from 3,000 to 8,000 adults annually. About 1,000 silver salmon spawn in the river each year.

An early season fishery is supported by yearling steelhead, trout, and silver salmon. By the end of May, when these fish leave the river on their way to the ocean, the fishery is dependent on resident trout and catfish.

Much of the success of any maintenance or enhancement plan on the Shasta River would depend on the temperature of the water released below the dams. Temperatures consistently above 56°F. during the salmon spawning

season would seriously interfere with development and survival of eggs. Maintenance and enhancement plans presented assume satisfactory water temperatures,

Two fisheries maintenance plans with the projects have been considered. The first plan is based on a combination of flow releases and artificial propagation facilities. The flow schedule of 66,000 acre-feet annually is based upon seasonal requirements of the fish for spawning and incubating purposes, and the minimum amount of water necessary to keep juvenile steelhead trout, silver salmon, and resident trout in good condition. Hatchery facilities would be needed to replace lost spawning areas.

In the second plan, hatchery facilities would be depended on to support the anadromous fishery. Only enough water would be released to provide migration flows and to provide for minimum spawning in the lower reaches of the river. No provision is made for the early season steelhead and silver salmon fishery. While flow releases would be reduced to 43,000 acre-feet per year, this plan should be adopted only as a last resort.

Two fisheries enhancement projects are presented, using flow schedules totaling 96,000 and 117,000 acre-feet annually. The 117,000 acre-foot schedule should provide benefits 20 percent greater than the 96,000 acre-foot schedule. The 96,000 acre-foot schedule was used in calculating benefits.

Without the proposed projects, the Shasta River fishery has an annual value of $337,000.

Enhancement values depend on the location of the proposed dams. Grenada Ranch Dam, operated for fisheries enhancement, would increase the

annual value of the fishery to $438,000; about a 29 percent increase. Gregory Mountain Dam would increase the annual value by about half as much.

With the enhancement flow of 96,000 acre-feet annually, Montague Dam would not increase the value of the fishery. Actually, a slight reduction would be expected.

RECOMMENDATIONS

The maintenance of the anadromous fish runs in the Shasta River depend on the release of sufficient quantities of water within the proper temperature range, and adequate artificial propagation facilities.

To determine whether these requirements can be met, further study is needed of the following:

1. Probable temperature of the water to be released from the proposed reservoirs.

2. Suitability of water for artificial propagation by operation of a pilot hatchery.

3. Suitability of artificial spawning channels as part of propagation facilities.

Assuming that suitable water temperatures would exist and that artificial propagation facilities can be developed, the following measures would be required to maintain the Shasta River fisheries:

1. A minimum release schedule of 66,000 acre-feet annually.

2. Hatchery facilities to replace lost spawning areas.

3. Multiple outlets or an outlet structure that would allow release of the water from different levels of the reservoir.

Enhancement of the fisheries would be possible if the following measures were adopted:

1. Flow release schedules of 96,000 to 117,000 acre-feet annually.

2. Multiple outlets to allow release of water from different levels of the reservoirs.

3. Construction of artificial spawning channels if they are feasible.

<u>General Recommendations</u>:

1. If possible, build only the Grenada Ranch Dam. This dam will eliminate the least amount of spawning area.

2. Construct upstream portion of development first, if more than one dam is required, to delay inundation of spawning grounds as long as possible.

3. Inform the Department of Fish and Game of any changes in the development plans. This will allow the department to keep management planning abreast of development plans.

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APPENDIX C

AGREEMENTS

APPENDIX C

TABLE OF CONTENTS

SECTION I

AGREEMENT

THIS AGREEMENT, made and entered into this 27th day of July, 1959, by and between THE CALIFORNIA OREGON POWER COMPANY, a California corporation (sometimes called CALIFORNIA OREGON POWER COMPANY or CALIFORNIA-OREGON POWER COMPANY), hereinafter called Copco. and STATE OF CALIFORNIA, by its duly authorized agencies, viz., the DEPARTMENT OF FISH AND GAME, hereinafter called the Department, and the FISH AND GAME COMMISSION, hereinafter called Commission,

W I T N E S S E T H:

WHEREAS, the State has filed and there is now pending an action against Copco in the Superior Court of the State of California, in and for the County of Siskiyou, numbered 13995, alleging that fluctuations in the flow of Klamath River resulting from operations of Copco on Klamath River constitute a public nuisance, which allegations at all times have been and now are denied by Copco, and

WHEREAS, Copco has heretofore filed an application with the Federal Power Commission in Project No. 2082, for a license to construct in two stages on Klamath River a facility known as the Iron Gate development, the first stage of which is designed to regulate the flow of water in said river so as to modify or eliminate said fluctuations, and

WHEREAS, Copco has also filed with the State Water Rights Board of the State of California an application, numbered 17527, to appropriate unappropriated water from Klamath River at the site of and in connection with said Iron Gate development, and

WHEREAS, the State has filed conditional protests or petitions for leave to intervene in the aforesaid proceedings before the Federal Power Commission and the State Water Rights Board, and

WHEREAS, the State is satisfied that the construction, maintenance and operation of said Iron Gate development as hereinafter provided will reregulate the flow of Klamath River in a manner satisfactory to the State, and

WHEREAS, it is the desire of the respective parties to resolve their differences through agreement and to facilitate the issuance of the necessary licenses and permits without formal hearings before the agencies involved so that Copco may proceed forthwith with the construction of the Iron Gate development and incidental fishery facilities mentioned in paragraph 3 below,

NOW, THEREFORE, in consideration of the mutual promises, covenants and agreements herein contained and in consideration of the premises, the respective parties hereby agree one with the other as follows:

1. Upon the receipt of a license from the Federal Power Commission, a permit from the State Water Rights Board, an approval of the Department of Water Resources (Division of Dams) and an order of the Public Utilities Commission of the State of California authorizing the same, Copco shall immediately commence the construction of, diligently prosecute to completion, and thereafter maintain and operate, the first stage of a reregulating facility near or at the site of its proposed Iron Gate development on Klamath River, Siskiyou County, California, as

described in its application dated January 10, 1957 filed with the Federal Power Commission in Project No. 2082, as such description may be modified by the license issued by the Federal Power Commission upon such application. Upon the completion of construction of such first stage, Copco shall operate said project so as to reregulate the flow of Klamath River in the following manner, subject to conditions beyond the control of Copco, and to the provisions of such license, permit and order:

(a) That Copco shall release over, around or through said Iron Gate development a minimum flow of not less than 710 cubic feet per second of water into the natural channel of Klamath River, for the protection and preservation of fish and wildlife;

(b) That the rate of fluctuation of flows of Klamath River below the said Iron Gate development shall not exceed 250 cubic feet per second of water per hour and that the change in river stage or elevation shall not exceed three inches (3") per hour as measured at a gauge located not more than one-half mile downstream from the said Iron Gate development, whichever produces the least amount of fluctuation.

2. If Copco shall construct the second stage of the said Iron Gate development, as described in its said application in Project No. 2082, or as such description may be modified by a license issued by the Federal Power Commission, Copco shall release over, around or through said Iron Gate development a flow of not less than 710 cubic feet per second of water into the natural channel of Klamath River and shall not fluctuate the flow of said river below the said Iron Gate development in

any manner or at all, subject to conditions beyond the control of Copco, and to the provisions of any applicable license, permit or order.

3. Concurrently with the construction of the first stage of the Iron Gate development, Copco shall construct permanent fish trapping and egg collecting facilities at or near and downstream from the Iron Gate development, to consist of structure, equipment and water supply for trapping and holding upstream anadromous migrants, in accordance with plans and specifications seasonably to be furnished by the Department, provided that Copco have any and all necessary authority so to do from any of the agencies mentioned in paragraph 1 of this agreement. The preliminary plan attached hereto and marked "Exhibit A" is intended to indicate generally the type of facilities contemplated by this paragraph; and while said preliminary plan is subject to revision, Copco shall not be required, in order to fulfill its obligations under this paragraph, to construct any facilities substantially more costly than those depicted on Exhibit A hereto. The facilities mentioned in this paragraph shall be located on property now owned by Copco; and title thereto, together with the land upon which they are situate and with right of ingress and egress, if necessary, over any lands now or hereafter owned by Copco; over reasonable routes designated by Copco, shall, upon completion of the facilities, be conveyed by Copco to the State; provided, that to the extent, if any, that said facilities are located on property or structures constituting "project works" of the Iron Gate development as defined in the Federal Power Commission license therefor, in lieu of title to the underlying property Copco shall convey to the State an easement to enter upon such property for all purposes in connection therewith.

4. Copco agrees to prepare and file, within thirty (30) days after the execution of this agreement (a) an application to the Public Utilities Commission of the State of California for an order granting a certificate of public convenience and necessity for construction of the first stage of the Iron Gate development, and (b) an application to the Department of Water Resources (Division of Dams) for approval of construction of the first stage of the Iron Gate development. If either of said agencies or the State Water Rights Board shall determine that its order or approval is not necessary, then the requirement of paragraph 1 hereof that such order or approval be obtained shall be deemed satisfied.

5. Subject to the requirements of any applicable license, permit or order, all project waters of Copco's facilities designated as F.P.C. Project No. 2082 shall be open to free public access and use for the purposes of hunting and fishing, provided, that subject to the provisions of low, Copco may restrict such access over such portions of the project waters and project waters and project property as may be reasonably needed by Copco for the protection of its facilities and for the protection of the public.

6. An executed copy of this agreement shall be delivered to the Federal Power Commission immediately upon the execution thereof, together with the request of each and all of the parties to this agreement that the application of Copco for a license to construct the said Iron Gate development shall issue forthwith, and without the necessity of any hearing by the Federal Power Commission in respect thereto which said hearing is now set for August 4, 1959, at Klamath Falls, Oregon, and that

said license, when issued, may include as conditions the provisions of the preceding paragraphs. In order to facilitate the issuance of the necessary license and permit:

(a) Copco shall file forthwith amendments to its applications in Project No. 2082 and its application now pending before the State Water Rights Board (No. 17527) by incorporating in said applications the terms and conditions of this agreement and requesting the two said agencies to issue permits and licenses expressly conditioned upon the terms and conditions of this agreement consistent with their respective jurisdiction; and

(b) The State, the Department and the Commission shall forthwith cause to be withdrawn and dismissed all protests and interventions with respect to the pending applications of Copco before the Federal Power Commission in Project No. 2082, and before the State Water Rights Board in Application No. 17527; provided, that the right is reserved to all parties hereto to be heard in any future proceedings in regard to fishery facilities, other than the fish trapping and egg collecting facilities referred to in paragraph 3 thereof.

7. Concurrently with the execution of this agreement, the State shall deliver to Copco an executed stipulation, in the form attached hereto and marked "Exhibit B", for the dismissal with prejudice of the action now pending in the Superior Court of the State of California, in and for the County of Siskiyou, numbered 13995, without costs to either party, and a release to Copco, in the form attached hereto and marked "Exhibit C", from all claims and demands for actual, punitive and all other damages,

arising at all times past and for such reasonable future period as may be required for construction of the Iron Gate development, from the alleged destruction of fish by Copco's present and past methods of fluctuating the flow of Klamath River. The parties hereto understand and agree that the effect of said dismissal with prejudice and said release will be that no claim will ever be made against Copco in the future for damages or any other relief arising out of any act or omission of Copco, up the date of this agreement and so long hereafter as Copco shall perform its obligations under this agreement, of the kind embraced within the complaint in said state court suit; but that the prosecution of any action hereafter brought, claiming relief by reason of alleged wrongful conduct of Copco occurring after the date of this agreement, shall not be prejudiced thereby.

8. The aforesaid release and dismissal shall be null and void in either of the following events: (a) if Copco shall reject, or shall fail or refuse to accept, or shall appeal from, or petition any court to review the issuance of, any license., permit, approval or order mentioned in paragraph 1 hereof; or (b) if Copco, except for reasons beyond its control, shall fail to commence the actual construction of the first stage of the Iron Gate development within sixty (60) days after receipt of the necessary license, permit, approval and order, and to complete the same within one (1) year thereafter; or (c) if Copco for any reason whatsoever shall fail to commence the actual construction of the first stage of the Iron Gate development within one hundred eighty (180) days after receipt of said license, permit, approval or order and to complete the same within eighteen (18) months thereafter; or (d) if any such license, permit,

approval or order for the construction of the first stage of the Iron Gate development shall be denied and such denial shall become final.

9. Copco agrees that it will not at any time request the Federal Power Commission to delete or modify Article 38 of its license for F.P.C. Project No. 2082, which Article was added to its said license by Supplemental Opinion and Order Amending Order Issuing License, issued February 28, 1956, and that it will not at any time request the Federal Power Commission that any of its hydroelectric plants on the Klamath River now covered by said license for Project No. 2082 (including the existing Copco No. 1 and Copco No. 2 plants and the proposed Iron Gate, Salt Caves, and Warm Springs developments) be removed from the coverage of said license.

10. This agreement shall be binding upon the successors and assigns of Copco.

11. Prior to the construction and operation of the first stage of the said Iron Gate development, Copco shall manually operate its existing Copco No. 1 and Copco No. 2 plants at Copco, California, so as to limit fluctuation of the surface of the Klamath River at a recording station located one-half (1/2) mile below the lower of said plants to a maximum of nine (9) inches per hour increase or decrease, and so that the minimum flow of said river at said point is 500 cubic feet per second, all subject to conditions beyond the control of Copco.

IN WITNESS WHEREOF the parties have executed this agreement at Sacramento, California, the day and year first above written.

THE CALIFORNIA OREGON POWER COMPANY

By______________________________
Vice President and General Manager

STATE OF CALIFORNIA, by its duly authorized agencies, viz.:

DEPARTMENT OF FISH AND GAME

By______________________________
Director

FISH AND GAME COMMISSION

By______________________________
President

APPROVED AS TO FORM:

STANLEY MOSK, Attorney General of the State of California

By s/s
RALPH W. SCOTT
Deputy Attorney General

STANLEY MOSK, Attorney General
RALPH W. SCOTT, Deputy
600 State Building
San Francisco 2, California
Telephone: UNderhill 1-8700

Attorneys for Plaintiff

IN THE SUPERIOR COURT OF THE STATE OF CALIFORNIA IN AND FOR

THE COUNTY OF SISKIYOU

THE PEOPLE OF THE STATE OF CALIFORNIA, Plaintiff,	)	No. 13995
vs.	)	DISMISSAL WITH PREJUDICE
CALIFORNIA OREGON POWER COMPANY, a corporation, et al., Defendants.	)	

Pursuant and subject to the terms of an agreement between the parties hereto dated July 27, 1959, the above-entitled action is hereby dismissed with prejudice.

STANLEY MOSK, Attorney General
RALPH W. SCOTT, Deputy

By______________________
Ralph W. Scott

Attorneys for Plaintiff

July 27, 1959

EXHIBIT B

RELEASE

Pursuant and subject to the terms of an agreement dated July 27, 1959 between THE CALIFORNIA OREGON POWER COMPANY, a California corporation (sometimes called CALIFORNIA OREGON POWER COMPANY or CALIFORNIA-OREGON POWER COMPANY), hereinafter called Copco, and STATE OF CALIFORNIA, by its duly authorized agencies, viz., the DEPARTMENT OF FISH AND GAME and the FISH AND GAME COMMISSION, the State hereby releases and forever discharges Copco, and all of its past and present directors, officers, employees and agents, and its and their successors, from any and all claims, demands, actions and causes of action, for any and all legal and equitable relief, arising at any time in the past, and for such reasonable future time as may be necessary for construction of the Iron Gate development referred to in said agreement, by reason of alleged conduct of Copco of the kind described in the complaint in an action in the Superior Court of the State of California, in and for the County of Siskiyou, No. 13995.

Done at Sacramento, California on July 27, 1959.

STATE OF CALIFORNIA, by its duly authorized agencies, viz.:

DEPARTMENT OF FISH AND GAME

By_________________________
Director

FISH AND GAME COMMISSION

By_________________________
President

EXHIBIT C

SECTION II

Edmund G. Brown
Governor

SEAL

STATE OF CALIFORNIA
STATE WATER RIGHTS BOARD

Kent Silverthorne, Chairman
W. P. Rowe, Member
Ralph J. McGill, Member

1401 21st Street
P.O. Box 1592
Sacramento 7, California

L. K. Hill
Executive Officer

March 24, 1960

Application 17527

To Applicant, Protestants
and Interested Parties:

Enclosed is a copy of Permit Order No. 136 of the State Water Rights Board adopted on March 22, 1960, in connection with Application 17527. The Board has approved the application and ordered that permit be issued subject to the terms and conditions set forth in the Order.

Very truly yours,

/s/ L. K. Hill
L. K. Hill
Executive Officer

Enclosure
Cert.

STATE OF CALIFORNIA
STATE WATER RIGHTS BOARD

1401 21st Street
P.O. Box 1592
Sacramento 7, California

PERMIT ORDER NO. 136

Application 17527
California Oregon Power Company
Klamath River, Siskiyou County

Application 17527 having been filed, protests having been submitted by the California Department of Fish and Game, California Department of Water Resources, and California Klamath River Commission; the protests having been satisfied by an agreement between the applicant and the California Department of Fish and Game and the California Fish and Game Commission, dated July 27, 1959, and a stipulation between the applicant and the California Department of Water Resources, dated January 26, 1960; the Board having considered the available information and now being fully informed in the premises:

IT IS HEREBY ORDERED that Application 17527 of the California Oregon Power Company be, and the same is approved, and that a permit be issued to the applicant subject to vested rights and to the following terms and conditions:

1. The amount of water to be appropriated for power purposes shall be limited to the amount which can be beneficially used and shall not exceed 3,300 cubic feet per second to be diverted from January 1 to December 31 of each year.

2. The maximum amount herein stated may be reduced in the license if investigation warrants.

3. Construction work shall begin on or before December 1, 1961.

4. Construction work shall be completed on or before December 1, 1964.

5. Complete application of the water to the proposed use shall be made on or before December 1, 1966.

6. Progress reports shall be filed promptly by permittee on forms which shall be provided annually by the State Water Rights Board until license is issued.

7. All rights and privileges under this permit including method of diversion, method of use, and quantity of water diverted are subject to the continuing authority of the State Water Rights Board in accordance with law and in the interest of the public welfare, to prevent waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of said water.

8. Any right acquired pursuant to this permit is subject and subordinate to water rights, whether heretofore or hereafter acquired, for the diversion of water from the Klamath River for use in the Shasta Valley-Ager area for higher uses, up to an annual quantity of 220,000 acre-feet, provided that, until March 1, 2006, and subject to vested rights, if any, the water rights to which this permit is subordinate shall be upon the following conditions:

(a) The maximum amount to be diverted shall not exceed 120,000 acre-feet in any water year (October 1 to September 30), and the maximum rate of diversion shall not exceed 300 cubic feet per second from May 16 to September 15 of each year, and 100 cubic feet per second from September 16 of each year to May 15 of the succeeding year; and

(b) Permittee under any future appropriation will make, or will have made, due compensation, fixed either by agreement with the present permittee or by eminent domain proceedings, for the right to enter upon or use any facilities of the present permittee, including the right to use any reservoir created by the present permittee as a point of diversion. This subsection shall not be deemed to imply that any person has a right to enter upon or use any facilities of the present permittee without making due compensation.

9. This permit is subject to the provisions of the Klamath River Basin Compact, 71 Stat. 497, and of Article 38 of the license issued by the Federal Power Commission for Project No. 2082, 15 F.P.C. 14, 22, insofar as such compact and article are by their terms applicable to the appropriation of water included under this permit.

10. Subject to conditions beyond its control, permittee shall release over, around or through Iron Gate Dam into the natural channel of the Klamath River for the preservation of fish and wildlife not less than the following amounts of water:

September 1 to April 30	1,300 cfs
May 1 to May 31	1,000 cfs
June 1 to July 31	710 cfs
August 1 to August 31	1,000 cfs

provided however, that permittee shall not be required to release more water than it has a lawful right to use for hydroelectric purposes.

11. Subject to conditions beyond its control, permittee shall not fluctuate the Klamath River provided that in the event it is necessary to decrease or increase the flow to or above the flows set forth in Condition 10 of this permit, the rate of change of flow shall not exceed 250 cfs of water per hour or the change in the river stage or elevation shall not exceed 3 inches per hour as measured at a gage located not more than 0.5 mile downstream from said Iron Gate development, whichever produces the least amount of fluctuation.

Adopted as the order of the State Water Rights Board at a meeting duly called and held at Sacramento, California, this 22nd day of March, 1960.

Kent Silverthorne, Chairman

W. P. Rowe, Member

Ralph J. McGill, Member

29980 9-61 800 SPO

LEGEND

BOUNDARY OF SHASTA RIVER BASIN

BOUNDARY OF HYDROGRAPHIC UNIT

EXISTING WATER SERVICE AGENCIES

BIG SPRINGS IRRIGATION DISTRICT

GRENADA IRRIGATION DISTRICT

MONTAGUE WATER CONSERVATION DISTRICT

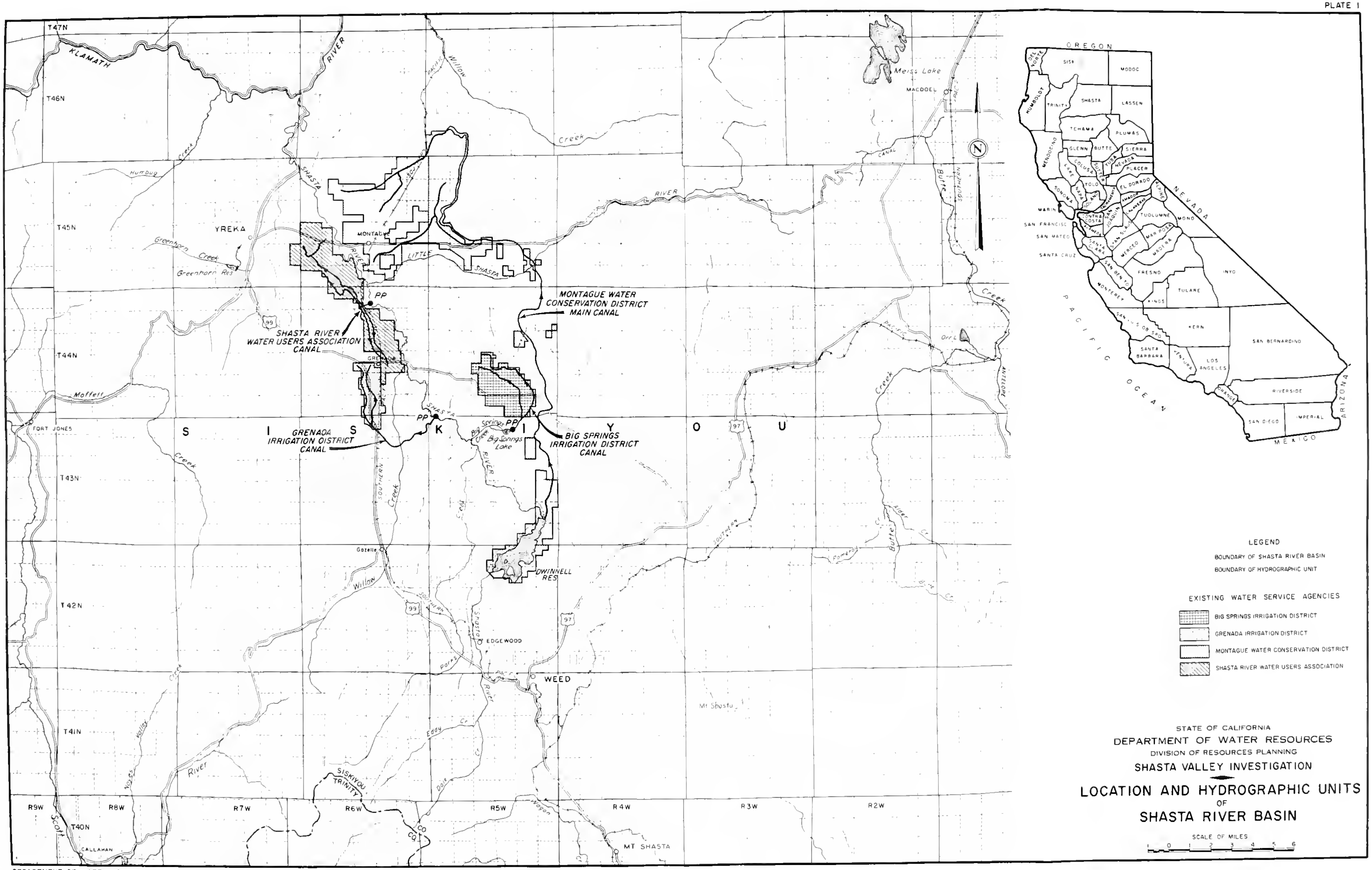
SHASTA RIVER WATER USERS ASSOCIATION

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

LOCATION AND HYDROGRAPHIC UNITS OF SHASTA RIVER BASIN

SCALE OF MILES

1 0 1 2 3 4 5 6



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

LOCATION AND HYDROGRAPHIC UNITS OF SHASTA RIVER BASIN

DEPARTMENT OF WATER RESOURCES 1961

EXPLANATION

UNCONSOLIDATED ROCKS

Recent

Qyal — YOUNGER ALLUVIUM

(Stream channel, flood-plan, and fan deposits, consisting of lenses of permeable sand and gravel in a clay matrix. Yields water for domestic, stock, and irrigation supplies)

Pleistocene to Recent

Qoal — OLDER ALLUVIUM

(Poorly sorted boulders, sand, and gravel in a clay matrix. Generally yields water sufficient for domestic and stock supplies).

Qfo — FLUVIOGLACIAL DEPOSITS

(Unstratified to poorly stratified bouldery deposits in a fine-grained matrix. Yield water for domestic, stock, and irrigation supplies at south end of Shasta Valley).

Pleistocene

Qm — MORAINAL DEPOSITS

(Unstratified bouldery deposits in a fine-grained matrix. Yield water for domestic, stock, and irrigation supplies at south end of Shasta Valley).

Qt — TERRACE DEPOSITS

(Gravel and sandy clay of limited extent; position generally above the water table).

QUATERNARY

CONSOLIDATED ROCKS

Recent

Qpb — PLUTO'S CAVE BASALT

(Black, vesicular, olivine-rich augite basalt. Yields abundant water for domestic, stock, and irrigation purposes).

Pliocene to Recent

QTb — VOLCANIC ROCKS OF THE HIGH CASCADES

(Lava flows of olivine basalt and basaltic andesite; important chiefly as a ground-water storage reservoir).

Eocene to Miocene

Tvw — VOLCANIC ROCKS OF THE WESTERN CASCADES

(Chiefly andesitic lavas and pyroclastic ejecta with subordinate flows of basalt and dacite, beds of rhy lite tuff, and a few rhyolite lava domes. Generally supplies sufficient water for domestic and stock supplies. Yields water for irrigation in Gazelle-Grenada area).

TERTIARY

Upper Cretaceous

Kh — HORNBROCK FORMATION

(Well bedded yellow to greenish-gray arkosic sandstone and graywacke; black shale in uppermost part. Locally yields water for domestic and stock supplies).

CRETACEOUS

Pre-upper Cretaceous

pK — BASEMENT COMPLEX

(Quartzitic schist, slightly metamorphosed sandstone, shale and limestone; meta-volcanic greenstone and intrusive periodotite (altered to serpentine) and granitic rocks. Locally yields water for domestic and stock supplies. Includes Abrams mica schist, Chanchelulla formation, and other rocks, undifferentiated).

PRE-CRETACEOUS

GEOLOGIC CONTACT

ALLUVIAL CONTACT

U
D
FAULT

Dashed where uncertain
U: upthrown side
D: downthrown side

10

STRIKE AND DIP OF BEDS

...nd Water Branch,
...the State of Calif-

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

GEOLOGIC MAP OF SHASTA VALLEY

1960

SCALE OF MILES

1 0 1 2 3

EXPLANATION

UNCONSOLIDATED ROCKS

Recent

Qyal — YOUNGER ALLUVIUM

(Stream channel, flood-plain, and fan deposits, consisting of lenses of permeable sand and gravel in a clay matrix. Yields water for domestic, stock, and irrigation supplies)

Pleistocene to Recent

Qoal — OLDER ALLUVIUM

(Poorly sorted boulders, sand, and gravel in a clay matrix. Generally yields water sufficient for domestic and stock supplies).

Qfo — FLUVIOGLACIAL DEPOSITS

(Unstratified to poorly stratified bouldery deposits in a fine-grained matrix. Yield water for domestic, stock, and irrigation supplies at south end of Shasta Valley).

Pleistocene

Qm — MORAINAL DEPOSITS

(Unstratified bouldery deposits in a fine-grained matrix. Yield water for domestic, stock, and irrigation supplies at south end of Shasta Valley).

Qt — TERRACE DEPOSITS

(Gravel and sandy clay of limited extent; position generally above the water table).

QUATERNARY

CONSOLIDATED ROCKS

Recent

Qpt — PLUTO'S CAVE BASALT

(Black, vesicular, olivine-rich augite basalt. Yields abundant water for domestic, stock, and irrigation purposes).

Pliocene to Recent

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(Lava flows of olivine basalt and basaltic andesite; important chiefly as a ground-water storage reservoir).

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(Chiefly andesitic lavas and pyroclastic ejecta with subordinate flows of basalt and dacite, beds of rhyolite tuff, and a few rhyolite lava domes. Generally supplies sufficient water for domestic and stock supplies. Yields water for irrigation in Gazelle-Grenada area).

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Dashed where uncertain
U: upthrown side
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STRIKE AND DIP OF BEDS

nd Water Branch,
the State of Calif-

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

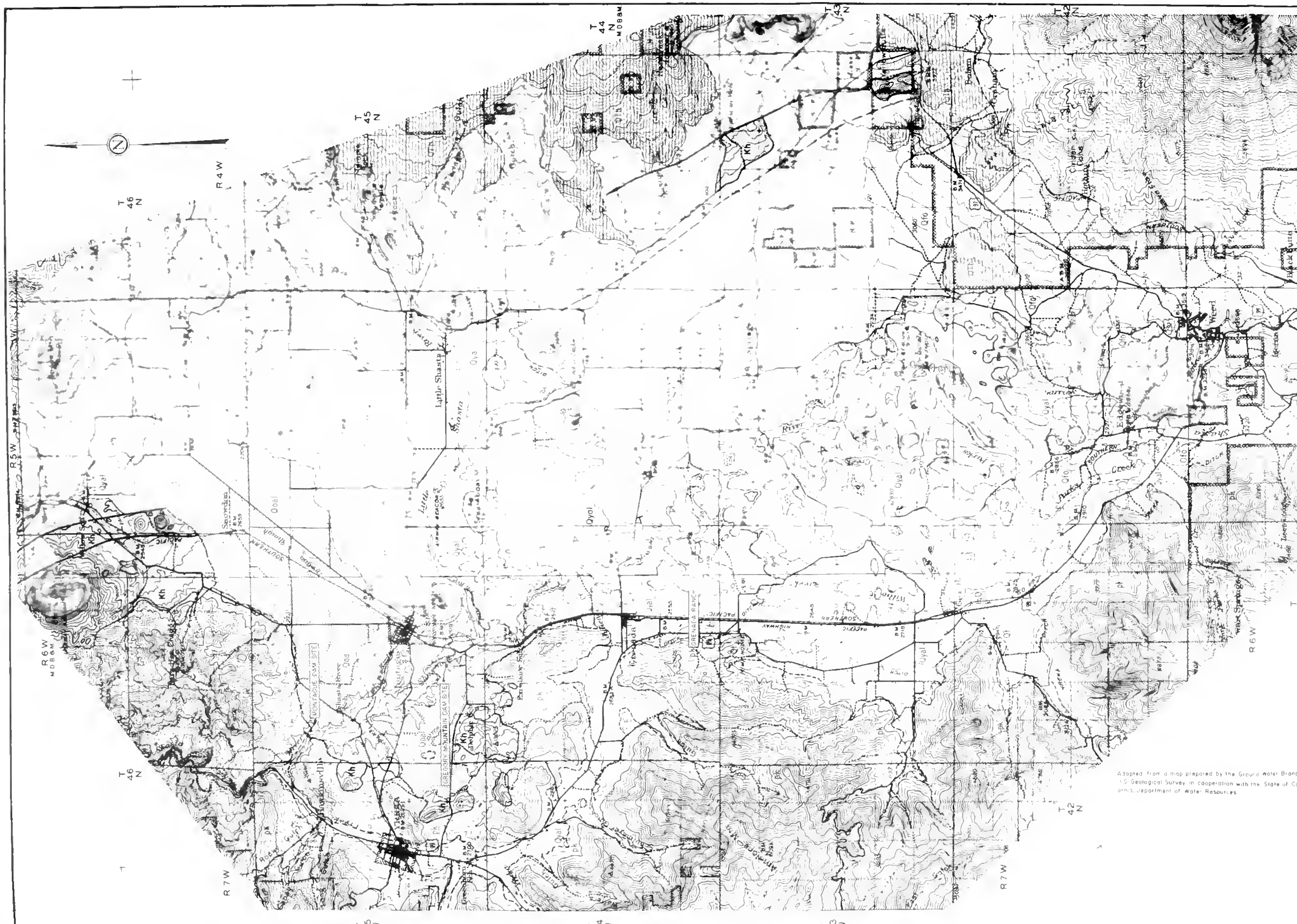
GEOLOGIC MAP OF SHASTA VALLEY

1960

SCALE OF MILES

1 0 1 2 3

PLATE A-1



EXPLANATION

UNCONSOLIDATED ROCKS

Qyal — YOUNGER ALLUVIUM

Qoal — OLDER ALLUVIUM

Qfo — PLUVIO-GLACIAL DEPOSIT

Qm

Qt

CONSOLIDATED ROCKS

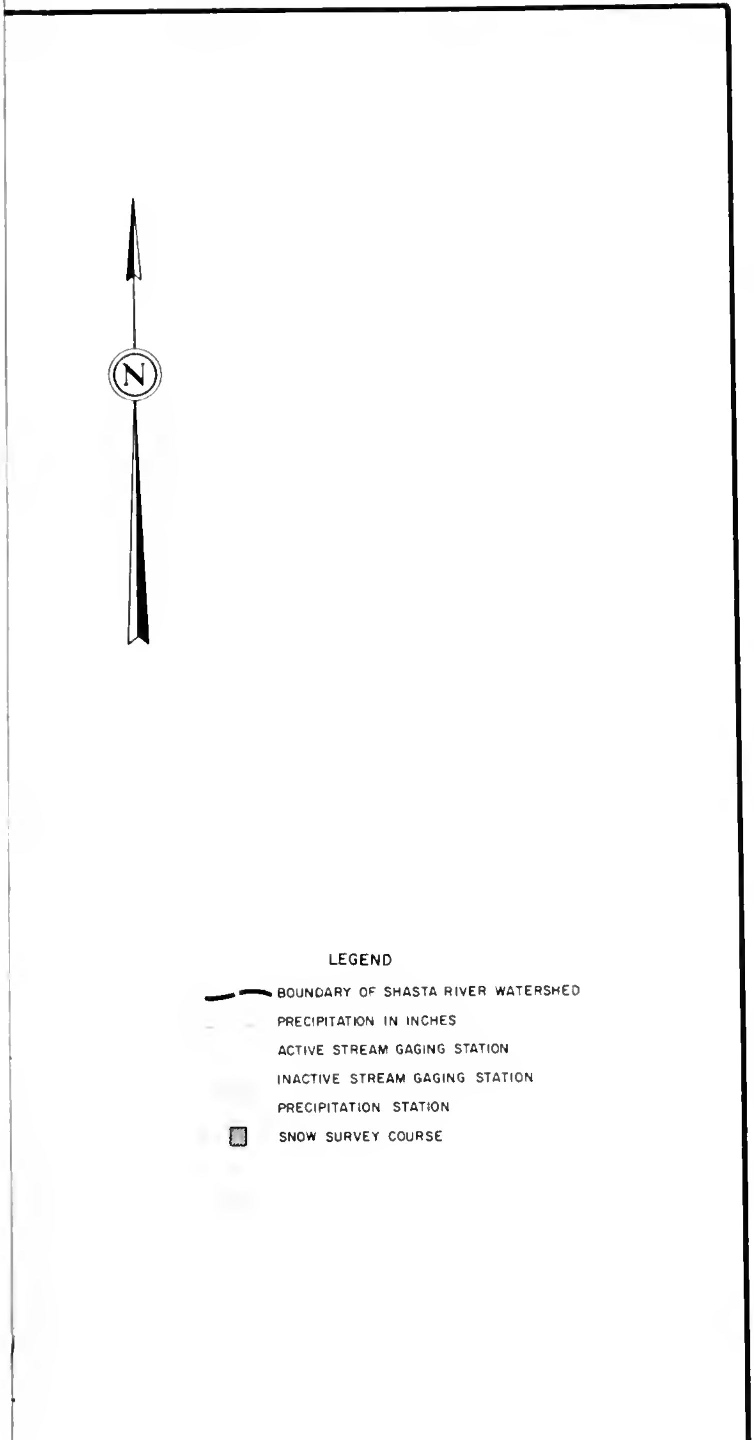
Kh

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

GEOLOGIC MAP OF SHASTA VALLEY

1960

SCALE OF MILES
0 1 2 3



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SHASTA VALLEY INVESTIGATION

LINES OF EQUAL MEAN SEASONAL PRECIPITATION FOR SHASTA VALLEY AND VICINITY 1905-06 THROUGH 1954-55

SCALE OF MILES
4 0 4 8 12

LEGEND

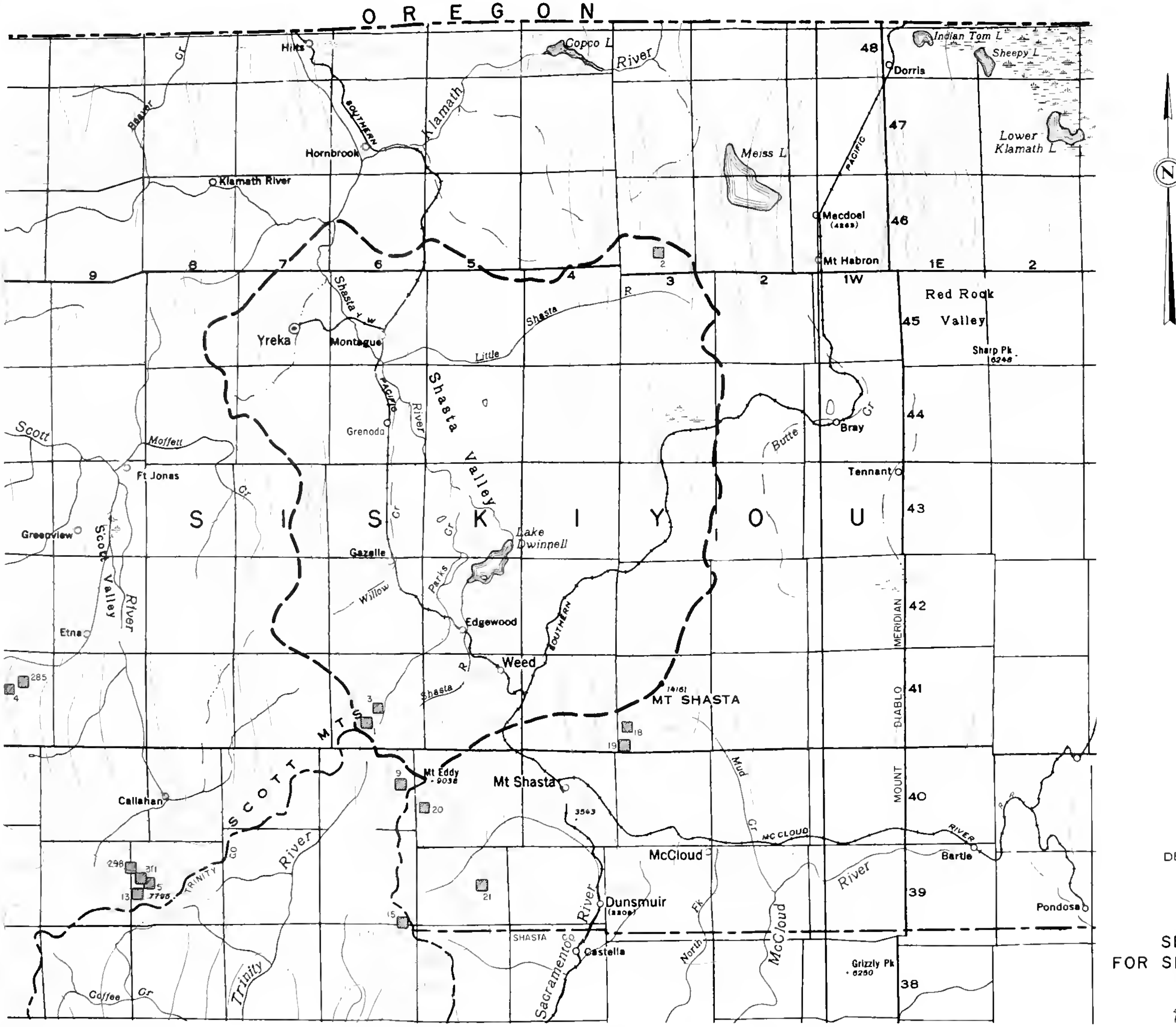
BOUNDARY OF SHASTA RIVER WATERSHED
PRECIPITATION IN INCHES
ACTIVE STREAM GAGING STATION
INACTIVE STREAM GAGING STATION
PRECIPITATION STATION
SNOW SURVEY COURSE

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SHASTA VALLEY INVESTIGATION

LINES OF EQUAL MEAN SEASONAL PRECIPITATION FOR SHASTA VALLEY AND VICINITY 1905-06 THROUGH 1954-55

SCALE OF MILES
4 0 4 8 12



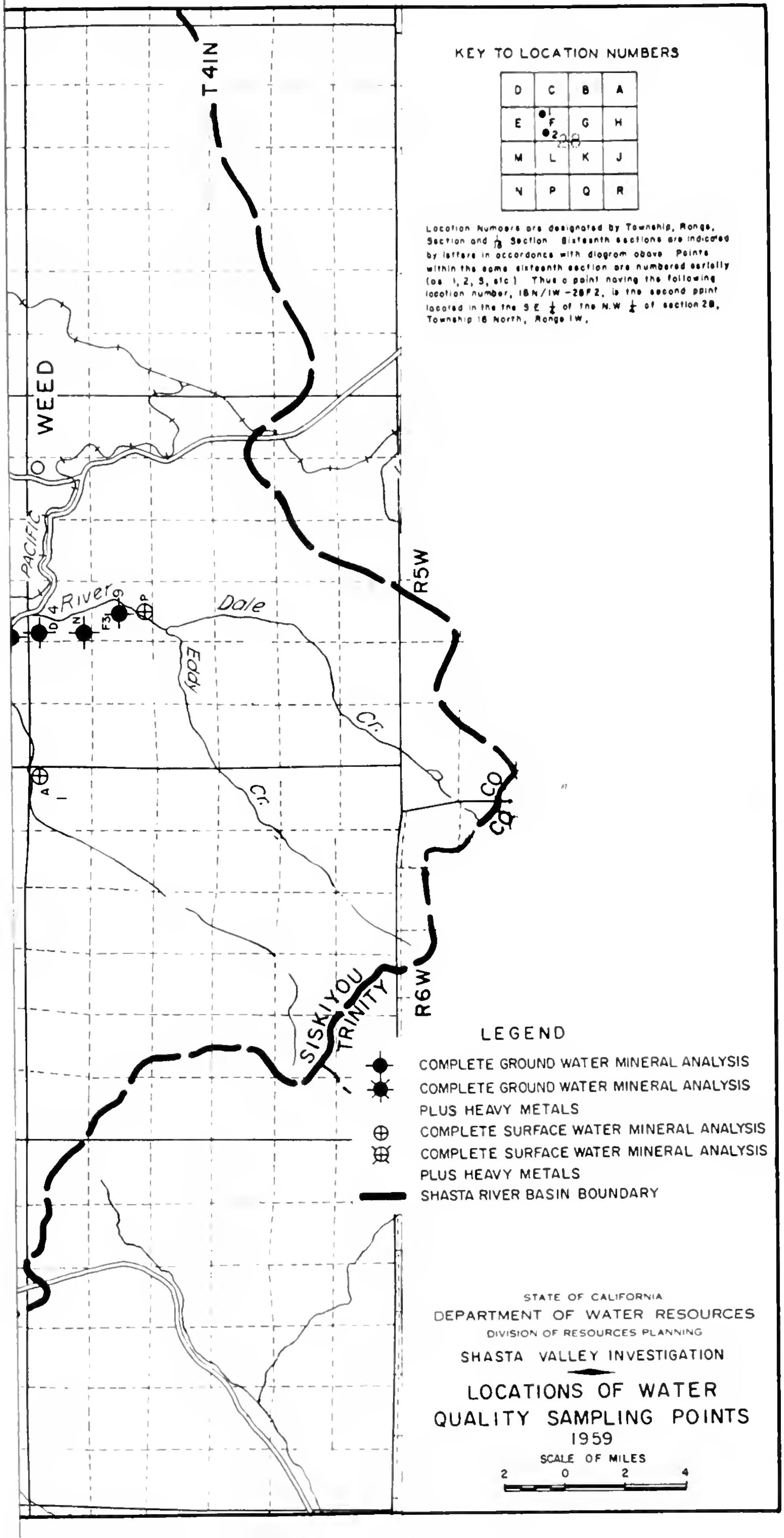
LEGEND

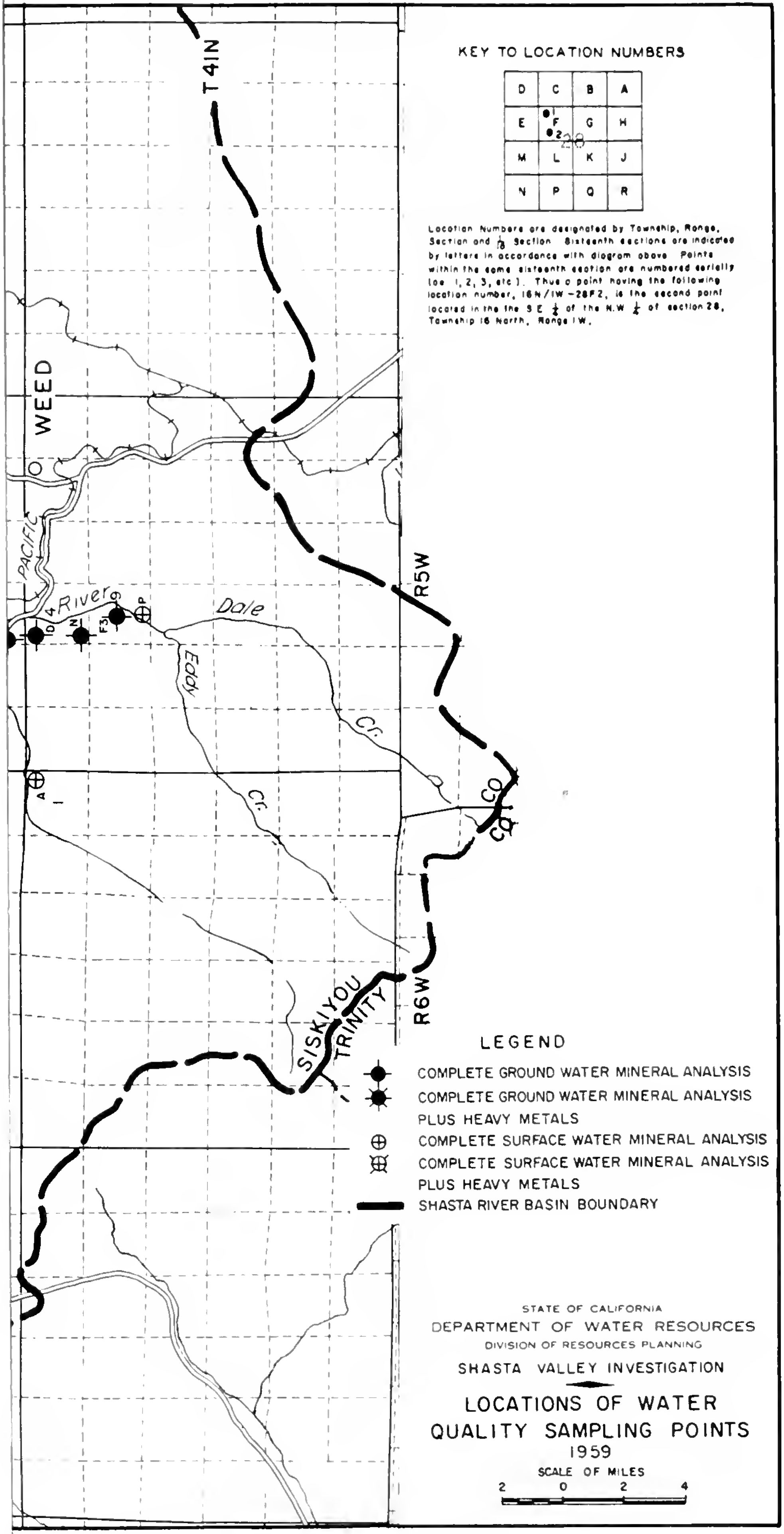
BOUNDARY OF SHASTA RIVER WATERSHED
PRECIPITATION IN INCHES
ACTIVE STREAM GAGING STATION
INACTIVE STREAM GAGING STATION
PRECIPITATION STATION
SNOW SURVEY COURSE

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

LINES OF EQUAL MEAN SEASONAL PRECIPITATION FOR SHASTA VALLEY AND VICINITY
1905-06 THROUGH 1954-55

SCALE OF MILES
4 0 4 8 12

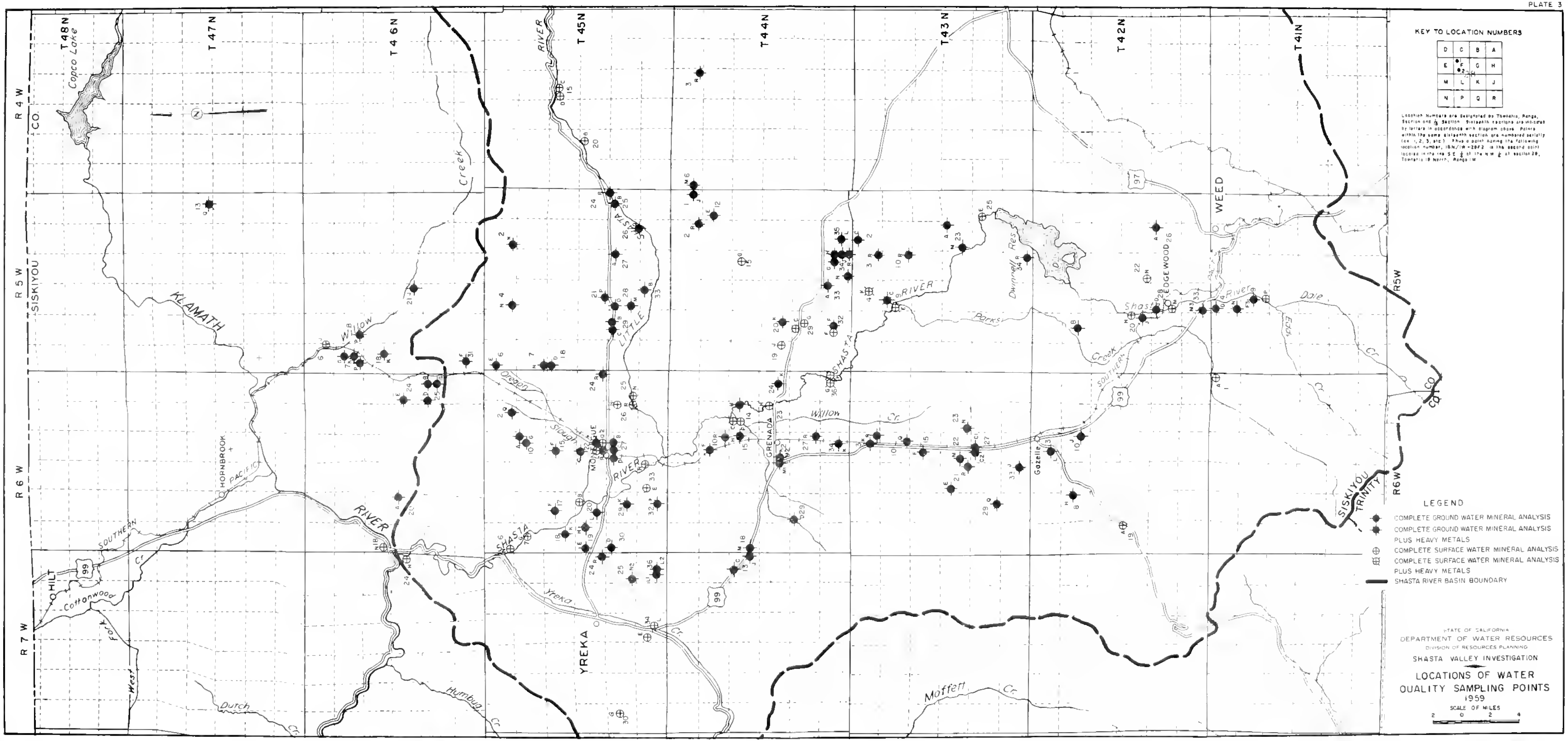

KEY TO LOCATION NUMBERS
D C B A
E F G H
M L K J
N P Q R
Location Numbers are designated by Township, Range, Section and 1/16 Section. Sixteenth sections are indicated by letters in accordance with diagram above. Points within the same sixteenth section are numbered serially (as 1, 2, 3, etc.). Thus a point having the following location number, 16N/1W-28F2, is the second point located in the the S.E. 1/4 of the N.W. 1/4 of section 28, Township 16 North, Range 1W.
T 41N
WEED
PACIFIC
River
Dale
Eddy
Cr.
Cr.
R5W
R6W
CO
CO
SISKIYOU
TRINITY
LEGEND
COMPLETE GROUND WATER MINERAL ANALYSIS
COMPLETE GROUND WATER MINERAL ANALYSIS PLUS HEAVY METALS
COMPLETE SURFACE WATER MINERAL ANALYSIS
COMPLETE SURFACE WATER MINERAL ANALYSIS PLUS HEAVY METALS
SHASTA RIVER BASIN BOUNDARY
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION
LOCATIONS OF WATER QUALITY SAMPLING POINTS
1959
SCALE OF MILES
2 0 2 4



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SHASTA VALLEY INVESTIGATION

LOCATIONS OF WATER QUALITY SAMPLING POINTS
1959


KEY TO LOCATION NUMBERS
D C B A
E F G H
M L K J
N P Q R
LEGEND
COMPLETE GROUND WATER MINERAL ANALYSIS
COMPLETE GROUND WATER MINERAL ANALYSIS PLUS HEAVY METALS
COMPLETE SURFACE WATER MINERAL ANALYSIS
COMPLETE SURFACE WATER MINERAL ANALYSIS PLUS HEAVY METALS
SHASTA RIVER BASIN BOUNDARY
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION
LOCATIONS OF WATER QUALITY SAMPLING POINTS
1959
SCALE OF MILES
2 0 2 4
T 48 N
T 47 N
T 46 N
T 45 N
T 44 N
T 43 N
T 42 N
T 41 N
R 4 W
R 5 W
R 6 W
R 7 W
R 5 W
R 6 W
Copco Lake
SISKIYOU CO.
KLAMATH RIVER
Willow Creek
LITTLE SHASTA RIVER
SHASTA RIVER
Oregon Slough
Willow Cr.
Parks Creek
Dwinnell Res.
Shasta River
Dale Cr.
Eddy Cr.
Yreka Cr.
Humbug Cr.
Dutch Cr.
Moffett Cr.
Cottonwood Cr.
West Fork
HORNBROOK
HILT
MONTAGUE
GRENADA
YREKA
Gazelle
EDGEWOOD
WEED
SOUTHERN PACIFIC
SISKIYOU TRINITY
CO. CO.
97
99

LEGEND

BOUNDARY OF SHASTA RIVER BASIN

GRENADA RANCH PROJECT SERVICE AREA

URBAN AREAS

PRESENTLY IRRIGATED LANDS (1955)

IRRIGABLE VALLEY LANDS

IRRIGABLE HILL LANDS

LANDS BEST SUITED TO FOREST MANAGEMENT

STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

DIVISION OF RESOURCES PLANNING

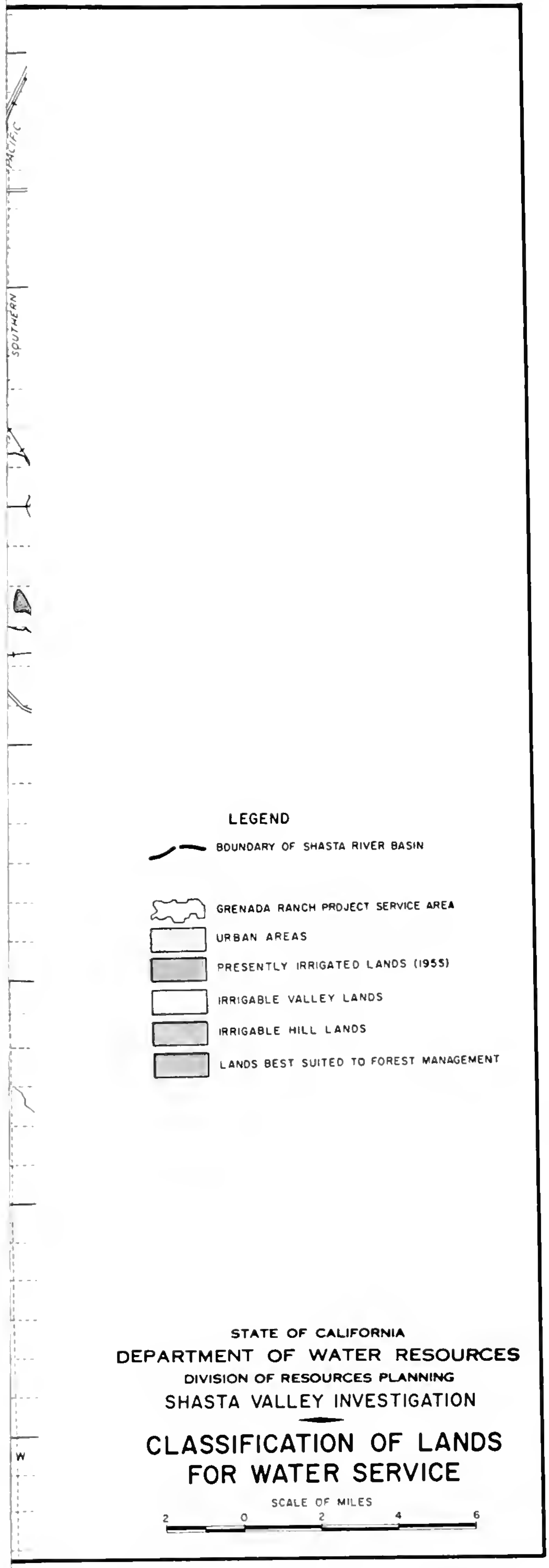
SHASTA VALLEY INVESTIGATION

CLASSIFICATION OF LANDS FOR WATER SERVICE

SCALE OF MILES

2 0 2 4 6

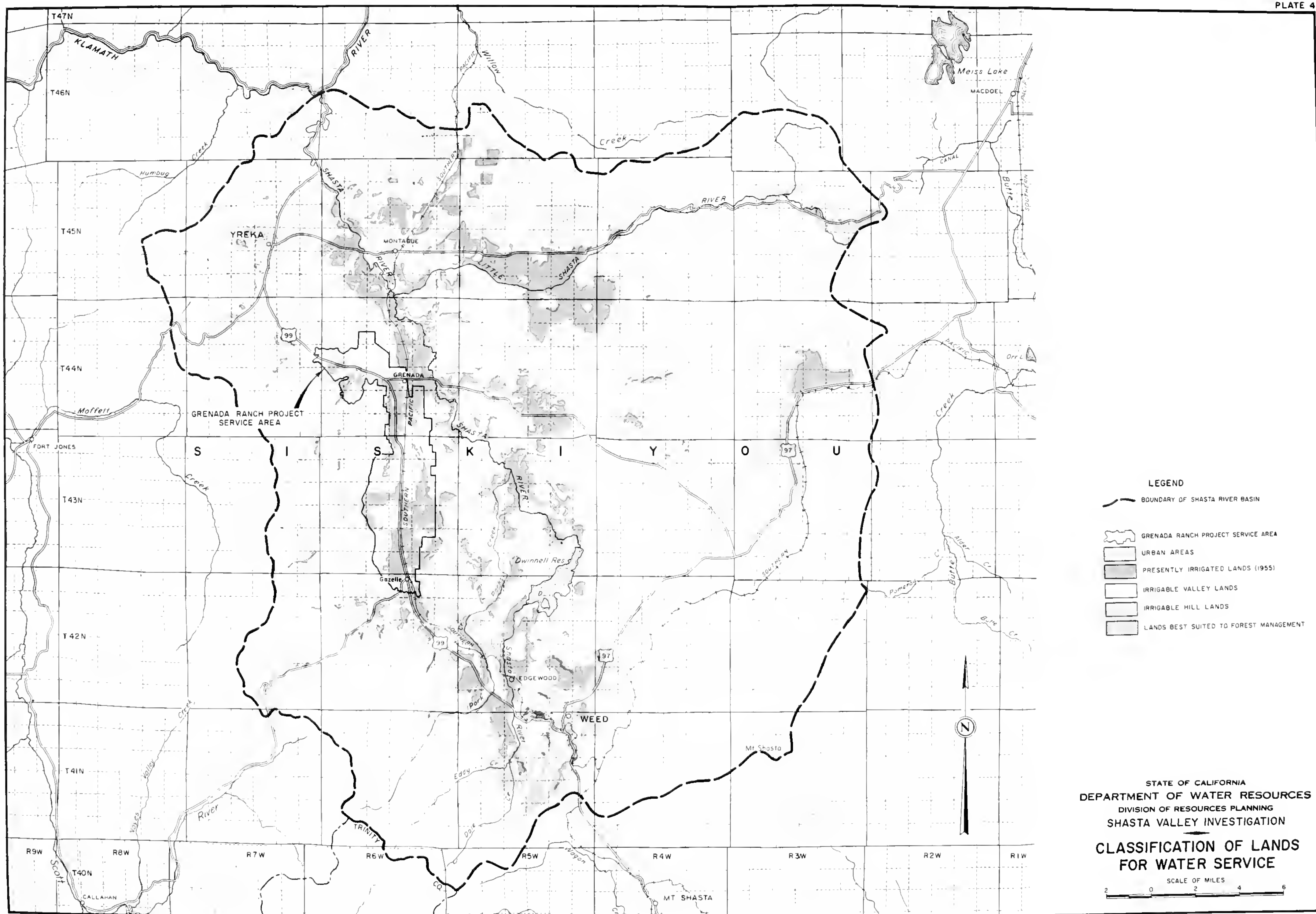
PLATE 4



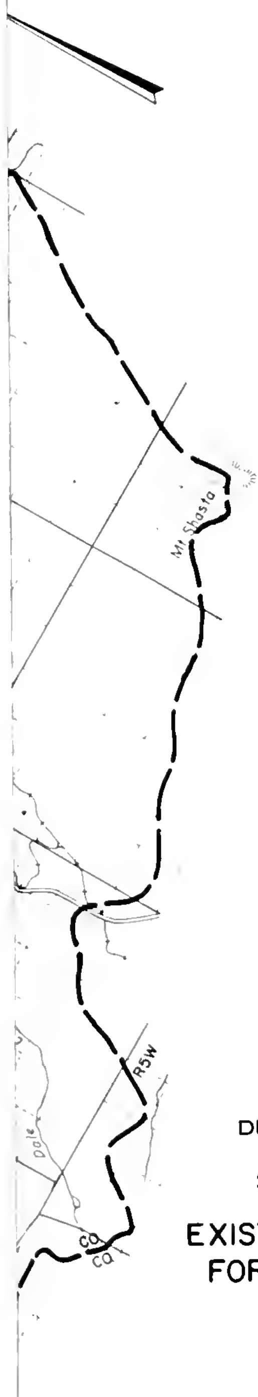
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

CLASSIFICATION OF LANDS FOR WATER SERVICE

SCALE OF MILES



DEPARTMENT OF WATER RESOURCES 1961



LEGEND

EXISTING DEVELOPMENT

FUTURE DEVELOPMENT

PUMPING PLANT

POWER HOUSE

BOUNDARY OF SHASTA RIVER BASIN

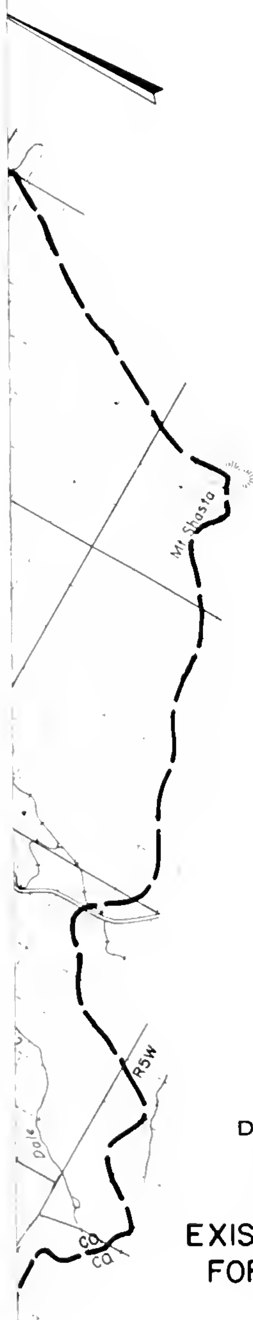
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

EXISTING AND POTENTIAL FACILITIES FOR WATER SUPPLY DEVELOPMENT OF SHASTA VALLEY

1960

SCALE OF MILES

2 0 2 4 6



LEGEND

EXISTING DEVELOPMENT

FUTURE DEVELOPMENT

PUMPING PLANT

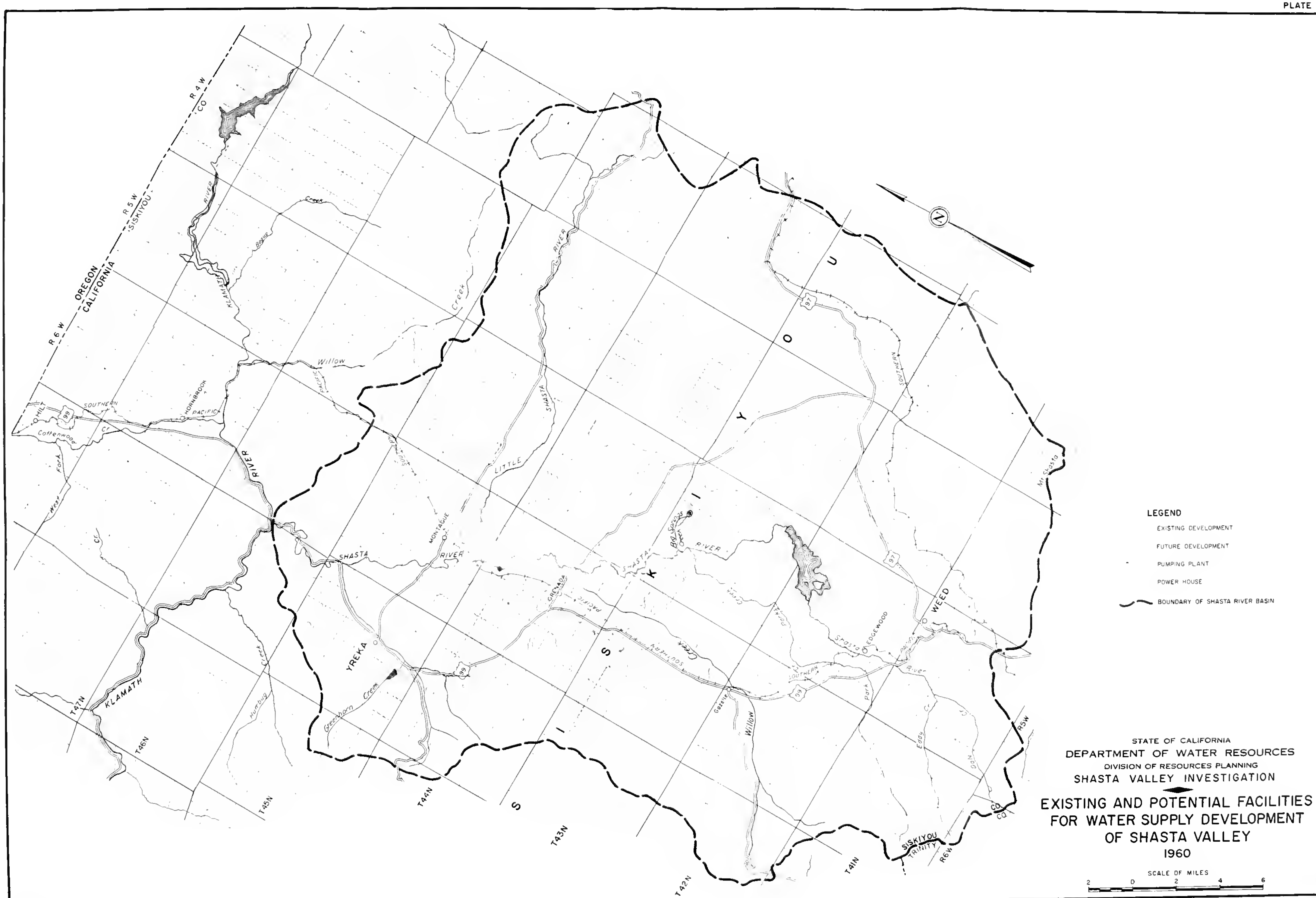
POWER HOUSE

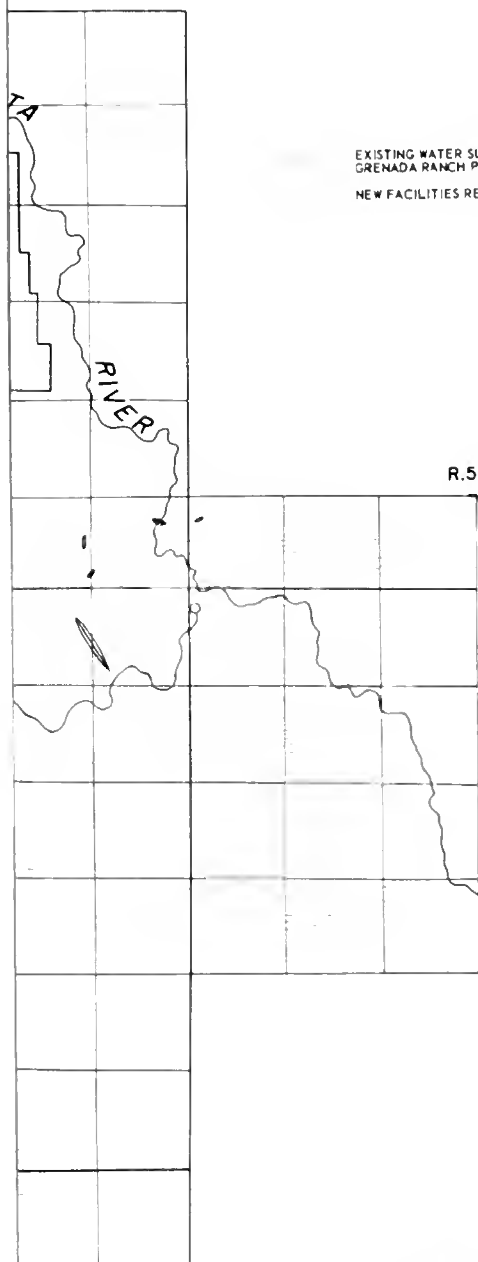
BOUNDARY OF SHASTA RIVER BASIN

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

EXISTING AND POTENTIAL FACILITIES FOR WATER SUPPLY DEVELOPMENT OF SHASTA VALLEY
1960

SCALE OF MILES
2 0 2 4 6


LEGEND
EXISTING DEVELOPMENT
FUTURE DEVELOPMENT
PUMPING PLANT
POWER HOUSE
BOUNDARY OF SHASTA RIVER BASIN
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION
EXISTING AND POTENTIAL FACILITIES
FOR WATER SUPPLY DEVELOPMENT
OF SHASTA VALLEY
1960
SCALE OF MILES
2 0 2 4 6
OREGON
CALIFORNIA
SISKIYOU CO
R 4 W
R 5 W
R 6 W
T47N
T46N
T45N
T44N
T43N
T42N
T41N
SISKIYOU
TRINITY
KLAMATH RIVER
SHASTA RIVER
LITTLE SHASTA RIVER
YREKA
MONTAGUE
GRENADA
HORNBROOK
HILT
EDGEWOOD
WEED
Mt Shasta
Gazelle
Willow Creek
Cottonwood Cr
West Fork
Humbug Creek
Greenhorn Creek
Bogus Creek
Big Springs
Parks Creek
Eddy Cr
SOUTHERN PACIFIC
99
97
S I S K I Y O U



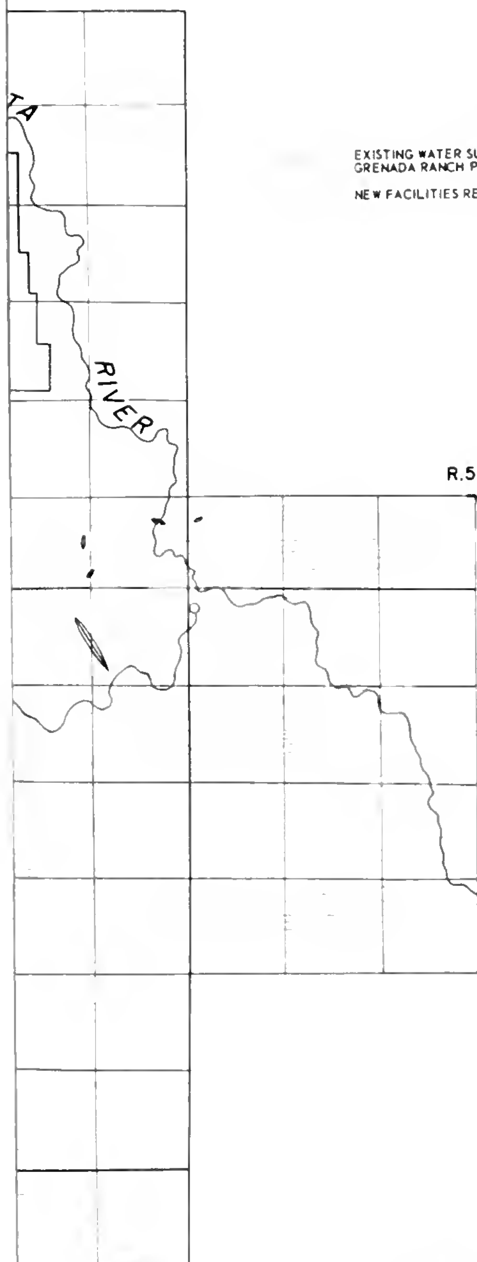
LEGEND

EXISTING WATER SUPPLY FACILITIES RELATED TO GRENADA RANCH PROJECT

NEW FACILITIES REQUIRED FOR GRENADA RANCH PROJECT

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

GRENADA RANCH PROJECT



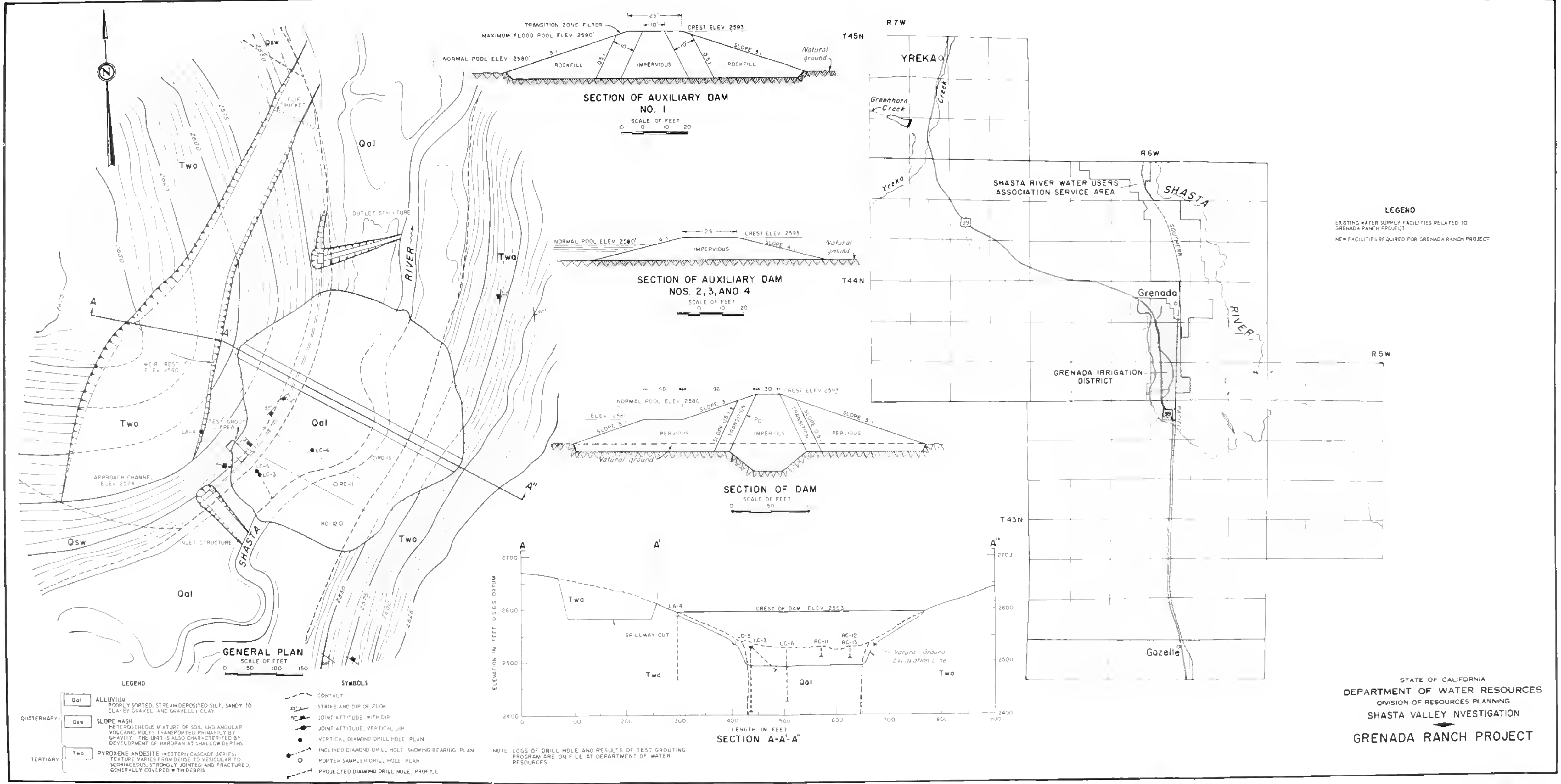
LEGEND

EXISTING WATER SUPPLY FACILITIES RELATED TO GRENADA RANCH PROJECT

NEW FACILITIES REQUIRED FOR GRENADA RANCH PROJECT

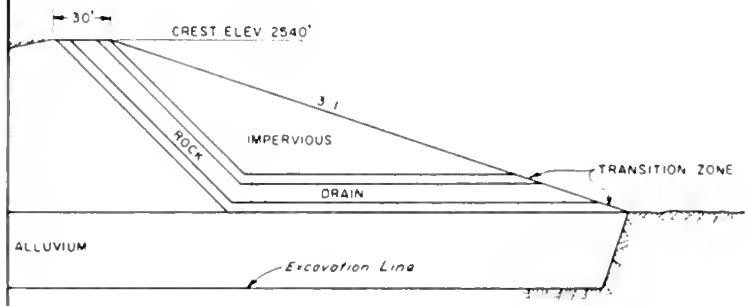
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

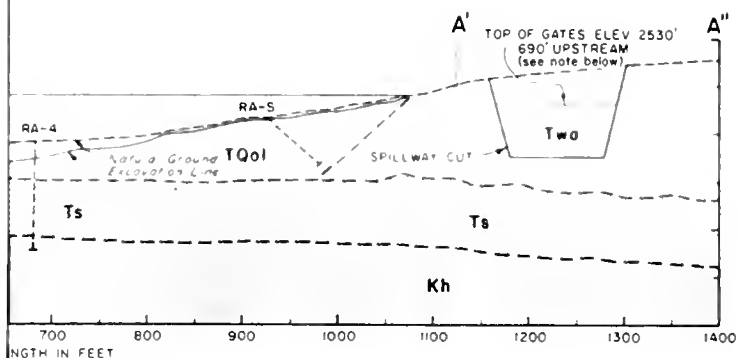
GRENADA RANCH PROJECT



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION
GRENADA RANCH PROJECT

DEPARTMENT OF WATER RESOURCES 1961





ION A-A'-A''

CLAY, SAND,

O UNCONSOLI-
DEPOSITED IN
TERIZED BY A
SURFACE AND
DPAN AT SHAL-

RIES)
TEXTURE
SCORIACEOUS,
VERY PER-
EBRIS

SEMI-
GRAVEL, SAND,

NE SANDSTONE
ELY MASSIVE

RBALANCED
TO RISE IN
TOP

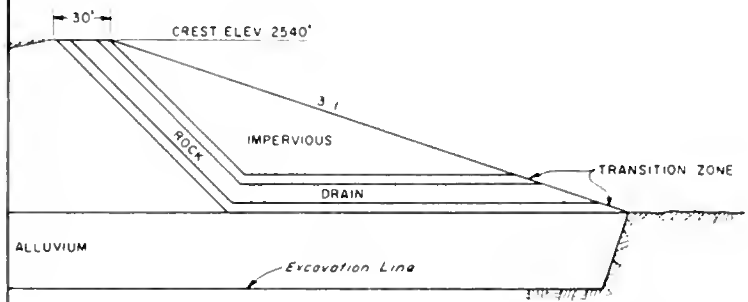
SYMBOLS

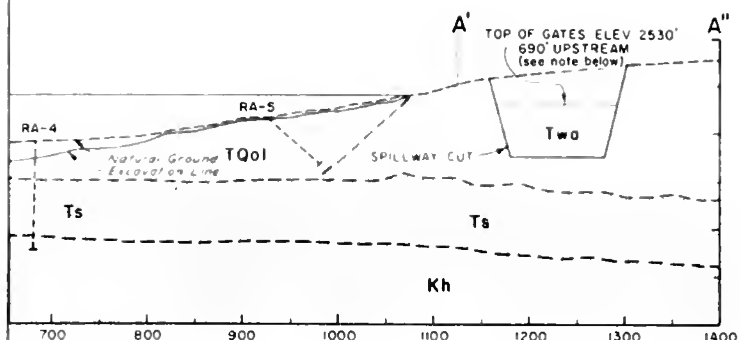
- CONTACT
- STRIKE AND DIP OF JOINTS
- VERTICAL DIAMOND DRILL HOLE, PLAN
- INCLINED DIAMOND DRILL HOLE, PLAN
- PROJECTED DIAMOND DRILL HOLE, PROFILE

NOTE: LOGS OF DRILL HOLES ARE ON FILE AT DEPARTMENT OF WATER RESOURCES

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

GREGORY MOUNTAIN DAM ON SHASTA RIVER





NGTH IN FEET

ION A-A'-A"

CLAY, SAND,

O UNCONSOLI-
DEPOSITED IN
TERIZED BY A
SURFACE AND
DPAN AT SHAL-

RIES)
TEXTURE
SCORIACEOUS,
VERY PER-
EBRIS

SEMI-
GRAVEL, SAND,

NE SANDSTONE
ELY MASSIVE

RBALANCED
TO RISE IN
TOP

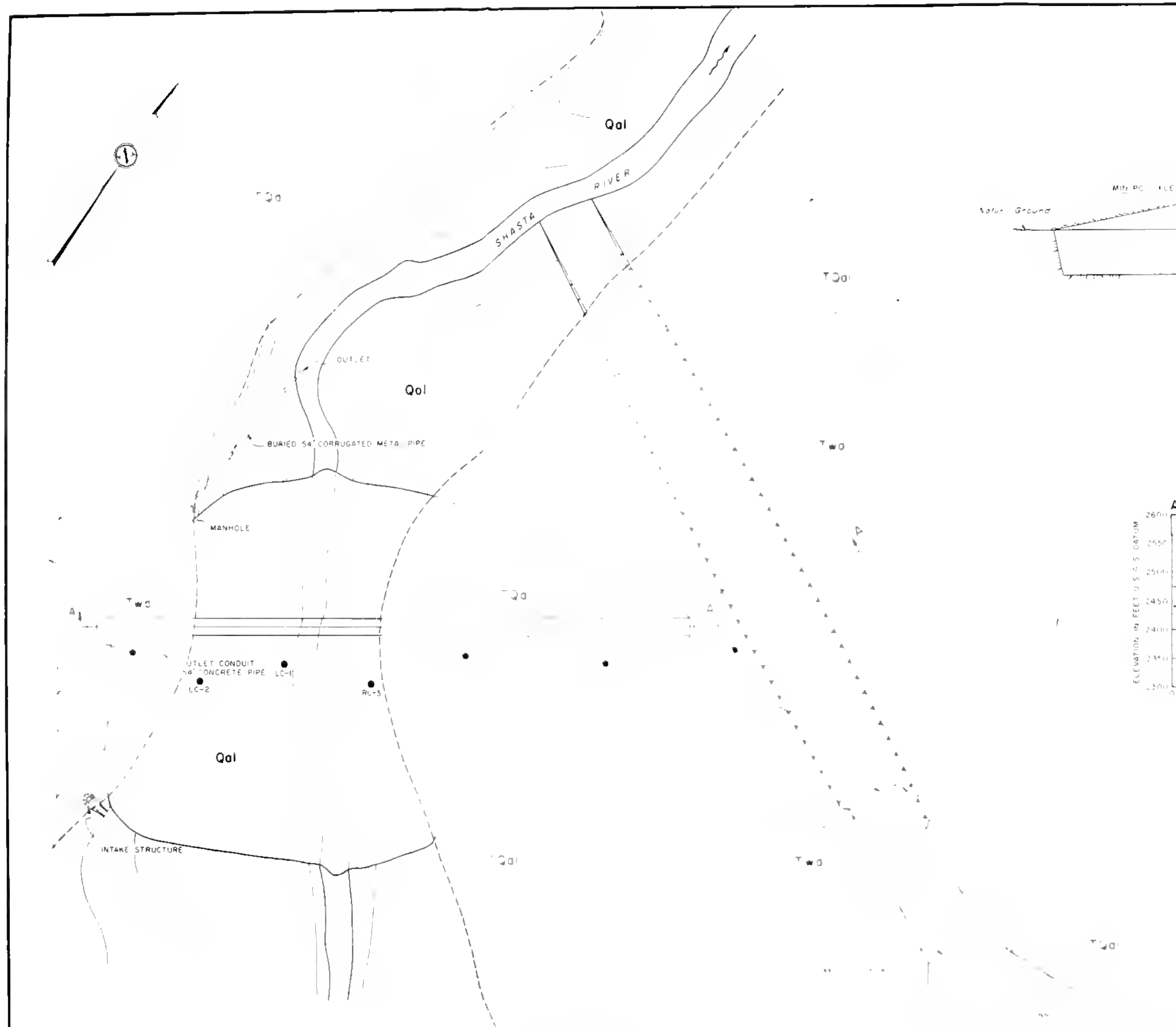
SYMBOLS

CONTACT
STRIKE AND DIP OF JOINTS
VERTICAL DIAMOND DRILL HOLE, PLAN
INCLINED DIAMOND DRILL HOLE, PLAN
PROJECTED DIAMOND DRILL HOLE, PROFILE

NOTE: LOGS OF DRILL HOLES ARE ON FILE AT DEPARTMENT OF WATER RESOURCES

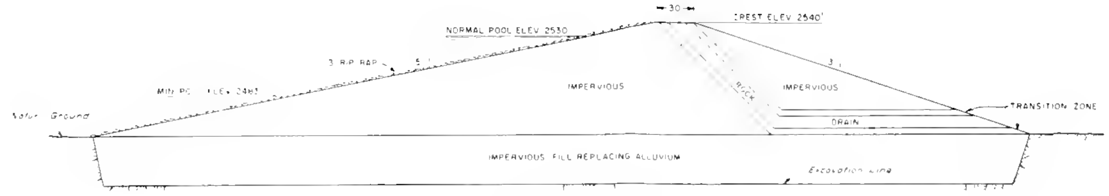
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

GREGORY MOUNTAIN DAM
ON SHASTA RIVER



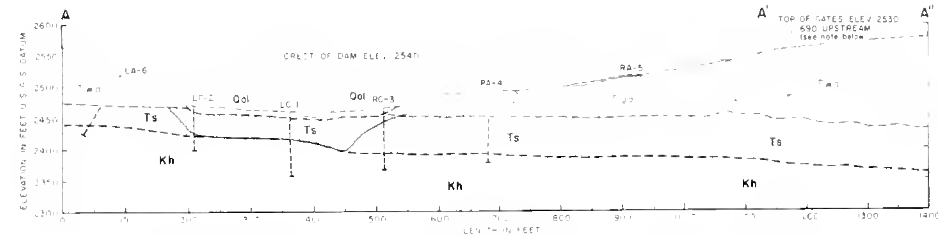
GENERAL PLAN

SCALE OF FEET



SECTION OF DAM

SCALE OF FEET



SECTION A-A'-A''

LEGEND

- Qal — ALLUVIUM
- OLDER ALLUVIUM
- VOLCANIC ROCKS
- Ts — SEDIMENTS
- Kh — HORNBROOK FORMATION

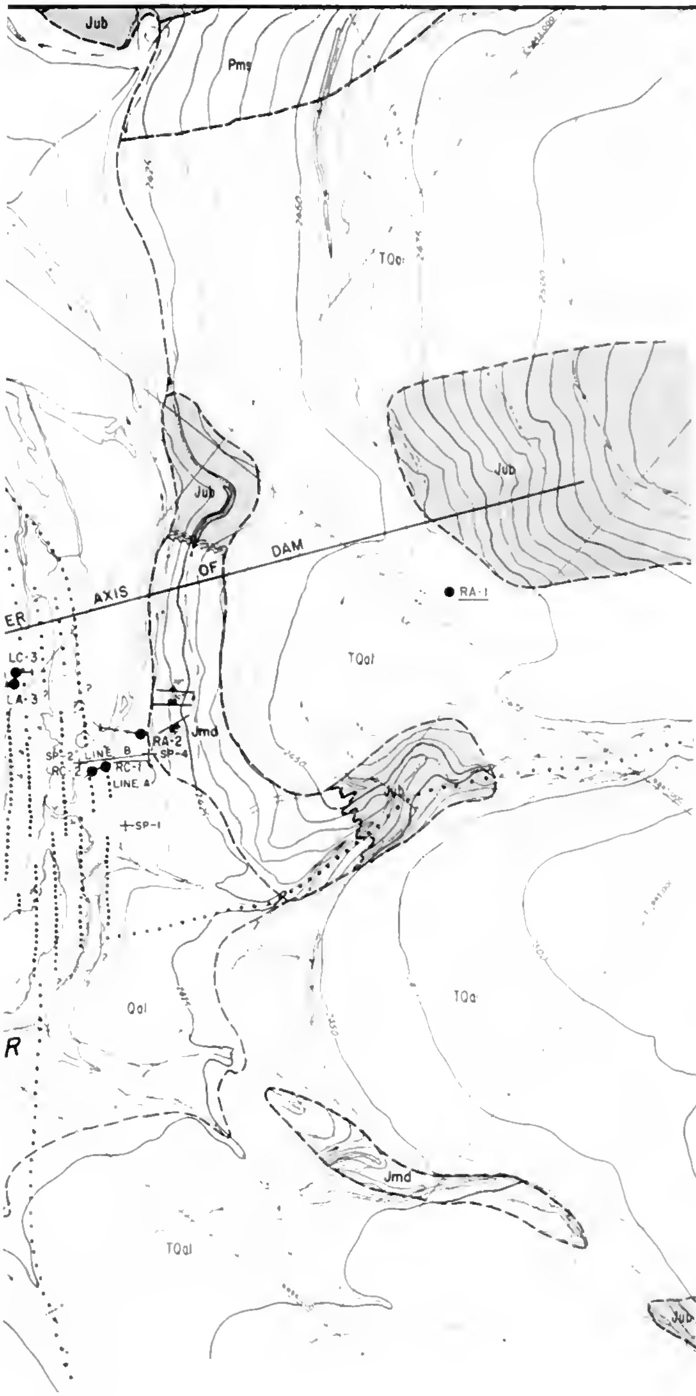
NOTE AUTOMATIC, FLOAT OPERATED COUNTERBALANCED GATES TO OPEN IN DIRECT RELATION TO RISE IN WATER SURFACE ABOVE THE NORMAL TOP ELEVATION OF THE CLOSED GATES

SYMBOLS

NOTE LOGS OF DRILL HOLES ARE ON FILE AT DEPARTMENT OF WATER RESOURCES

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION

GREGORY MOUNTAIN DAM ON SHASTA RIVER



LEGEND

QUATERNARY	Qal	RECENT ALLUVIUM STREAM DEPOSITED, POORLY SORTED GRAVELLY CLAY AND GRAVELLY SILTY SAND
TERTIARY	TQal	OLDER ALLUVIUM POORLY SORTED BEDS DEPOSITED IN COALESCING ALLUVIAL FANS, CHARACTERIZED BY A CONCENTRATION OF BOULDERS ON THE SURFACE AND THE FORMATION OF CLAY PAN OR HARD-PAN AT SHALLOW DEPTH
JURASSIC(?)	Jub	ULTRABASIC ROCKS PARTIALLY TO COMPLETELY SERPENTINIZED PYROXENITE AND PERIDODTITE USUALLY SHEARED AND OFTEN BRECCIATED OCCURS IN STEEPLY DEEPING SILL LIKE INTRUSIONS
	Jmd	METADIORITE HARD, MASSIVE TO SCHISTOSE COARSELY CRYSTALLINE ROCK OCCURS AS IRREGULAR POD-LIKE SEGREGATIONS IN THE ULTRA BASIC ROCK
PALEOZOIC	Pms	METASEDIMENTARY ROCKS INTERBEDDED MARBLE, QUARTZ MICA SCHIST, AND QUARTZITE ROCKS ARE HIGHLY DEFORMED BUT RELATIVELY HARD

SYMBOLS

	CONTACT
	FAULT ZONE
	FAULT TRACE
	SHEAR
30°	STRIKE AND DIP OF JOINTS
35°	STRIKE AND DIP OF SCHISTOSITY
85°	GENERALIZED STRIKE AND DIP OF CRUMPLED BEDS
	VERTICAL DIAMOND DRILL HOLE
	INCLINED DIAMOND DRILL HOLE SHOWING BEARING
LINE B, SP-2, SP-4	SEISMIC LINE AND SHOT POINTS

NOTES

Grid based on California Coordinate System Zone I

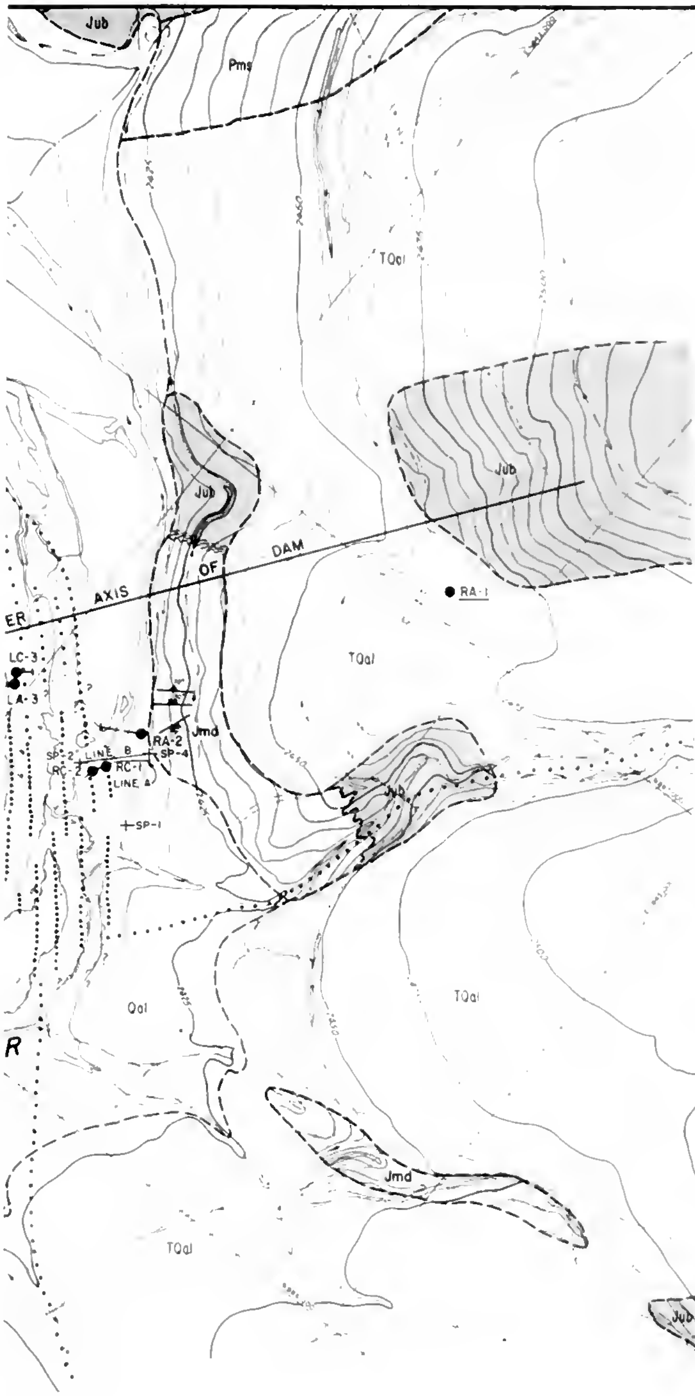
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SHASTA VALLEY INVESTIGATION

GEOLOGIC MAP UPPER AND LOWER AXIS MONTAGUE DAM SITE

SCALE OF FEET
100 0 100 200 300

Contour Interval 5 Feet



LEGEND

QUATERNARY

Qal — RECENT ALLUVIUM
STREAM DEPOSITED, POORLY SORTED, GRAVELLY CLAY AND GRAVELLY SILTY SAND

TERTIARY

TQal — OLDER ALLUVIUM
POORLY SORTED BEDS DEPOSITED IN COALESCING ALLUVIAL FANS, CHARACTERIZED BY A CONCENTRATION OF BOULDERS ON THE SURFACE AND THE FORMATION OF CLAY PAN OR HARD-PAN AT SHALLOW DEPTH

JURASSIC(?)

Jub — ULTRABASIC ROCKS
PARTIALLY TO COMPLETELY SERPENTINIZED PYROXENITE AND PERIODOTITE, USUALLY SHEARED AND OFTEN BRECCIATED. OCCURS IN STEEPLY DEEPING SILL LIKE INTRUSIONS

Jmd — METADIORITE
HARD, MASSIVE TO SCHISTOSE COARSELY CRYSTALLINE ROCK. OCCURS AS IRREGULAR POD-LIKE SEGREGATIONS IN THE ULTRA BASIC ROCK

PALEOZOIC

Pms — METASEDIMENTARY ROCKS
INTERBEDDED MARBLE, QUARTZ MICA SCHIST, AND QUARTZITE. ROCKS ARE HIGHLY DEFORMED BUT RELATIVELY HARD

SYMBOLS

CONTACT
FAULT ZONE
FAULT TRACE
SHEAR
30° STRIKE AND DIP OF JOINTS
35° STRIKE AND DIP OF SCHISTOSITY
85° GENERALIZED STRIKE AND DIP OF CRUMPLED BEDS
VERTICAL DIAMOND DRILL HOLE
INCLINED DIAMOND DRILL HOLE, SHOWING BEARING
LINE B, SP-2, SP-4 — SEISMIC LINE AND SHOT POINTS

NOTES

Grid based on California Coordinate System Zone I

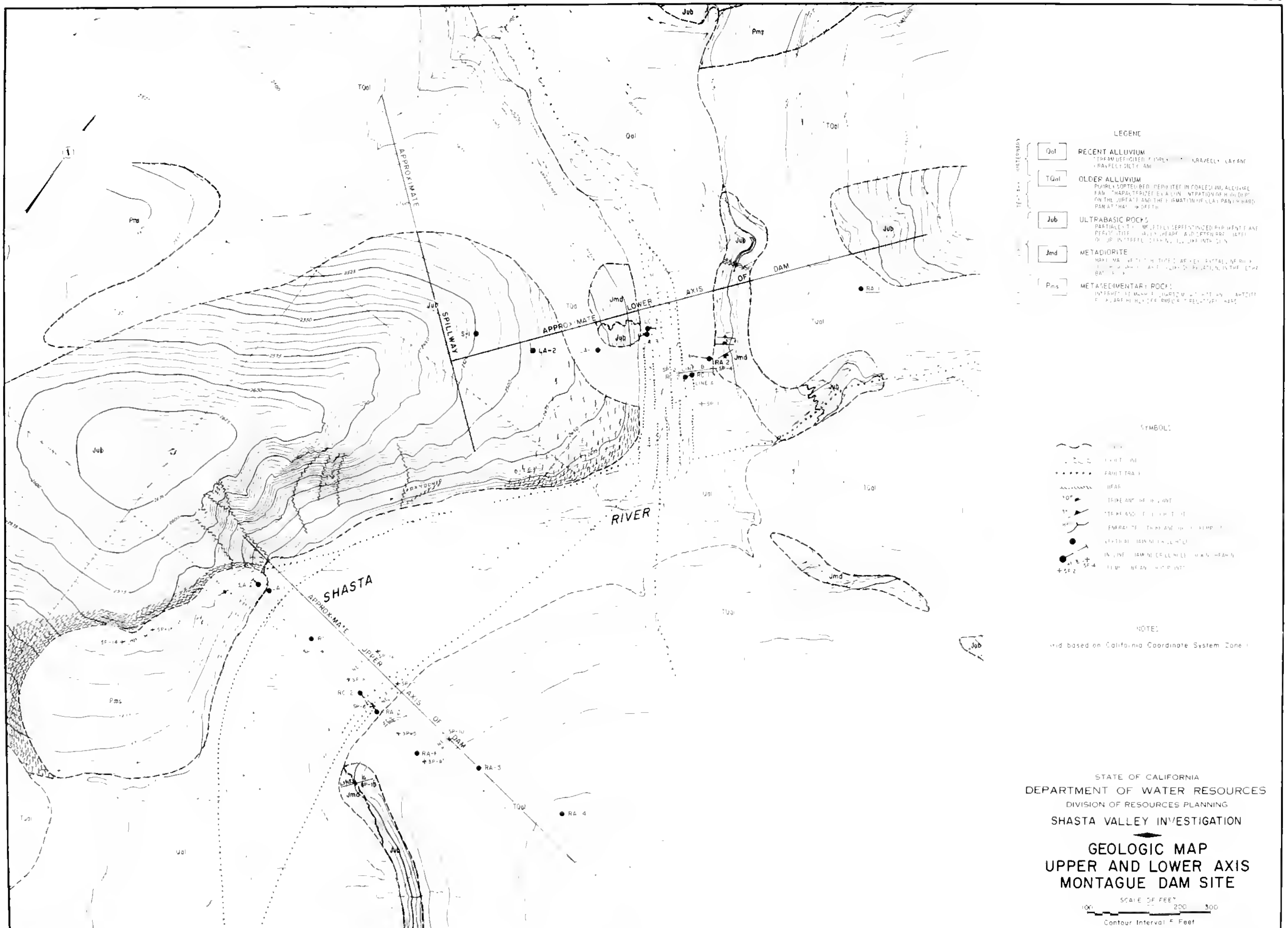
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SHASTA VALLEY INVESTIGATION

GEOLOGIC MAP
UPPER AND LOWER AXIS
MONTAGUE DAM SITE

SCALE OF FEET
100 0 100 200 300

Contour Interval 5 Feet


LEGEND
Qal RECENT ALLUVIUM
TQal OLDER ALLUVIUM
Jub ULTRABASIC ROCKS
Jmd METADIORITE
Pms METASEDIMENTARY ROCKS
SYMBOLS
NOTES
Grid based on California Coordinate System Zone I
APPROXIMATE LOWER AXIS OF DAM
APPROXIMATE UPPER AXIS OF DAM
APPROXIMATE SPILLWAY
SHASTA RIVER
LA-2
RA-2
RA-3
RA-4
RC-2
LINE B
LINE A
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA VALLEY INVESTIGATION
GEOLOGIC MAP
UPPER AND LOWER AXIS
MONTAGUE DAM SITE
SCALE OF FEET
100 0 100 200 300
Contour Interval 5 Feet